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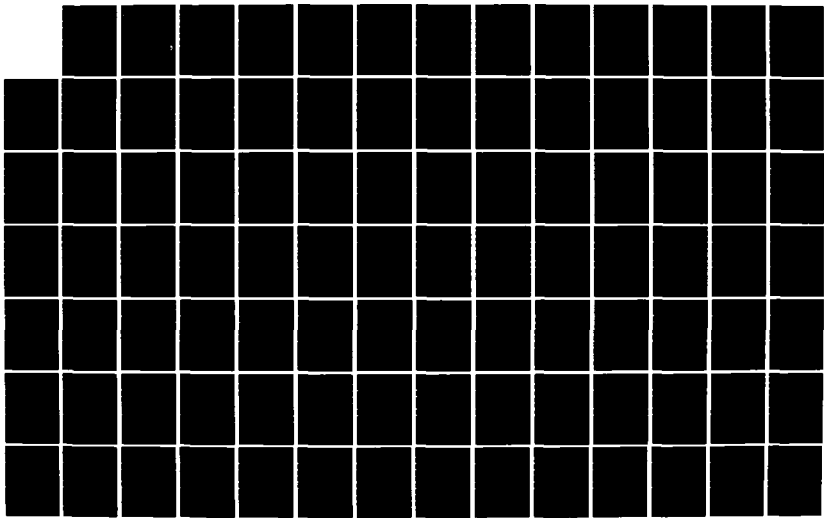
ELECTRONIC DELIVERY SYSTEM: PRESENTATION FEATURES(U)
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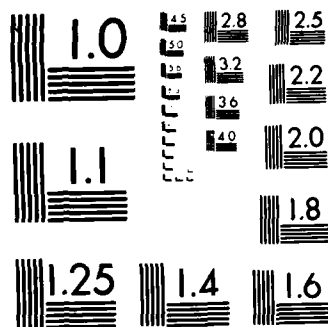
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ELECTRONIC DELIVERY SYSTEM
PRESENTATION FEATURES

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Presentation Features, Electronic Delivery Systems, Instructional Media, Job Training Program, Skill Performance Aids, SPA, Training Extension Course, TEC, Electronic Information Delivery Systems, Graphic Displays, Visual Displays, Videodisc, Computer-Assisted Instruction, Intelligent Videodisc		
20. ABSTRACT (Continue on reverse side if necessary and identify by block number)		
<p>This report describes design considerations for the human interface with electronic delivery systems. Five types of systems are described for (1) delivery of instruction, (2) administration and management, (3) job aiding in the field, (4) authoring, and (5) data entry for scoring and inventory in the field.</p> <p>Among the features considered are color, motion, sound,</p>		

resolution, realism, interaction processes, and input /
output devices.

Letter on file



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S U M M A R Y

THE PROBLEM

- THE NEXT WAR IS LIKE TO BE "COME AS YOU ARE," WITH LITTLE TIME TO MOBILIZE AND TRAIN. THEREFORE HIGH COMBAT READINESS IS CRITICAL.
- YET WE FACE REDUCED COMBAT READINESS AND EFFECTIVENESS CAUSED BY

TECHNOLOGICAL CHANGES:

- MORE, AND MORE COMPLEX NEW WEAPONS SYSTEMS (E.G., TOW, DRAGON, ROLAND)
- MORE TECHNOLOGY IN NON-COMBAT ACTIVITIES

SOCIETAL CHANGES:

- THE LABOR POOL IS SHRINKING
- MORE COMPETITION FROM BUSINESS, INDUSTRY, AND WELFARE
- HIGH TURNOVER OF PERSONNEL IN THE ARMED SERVICES
- MORE NON-ENGLISH SPEAKERS
- FEWER PEOPLE WHO HAVE BEEN SUCCESSFUL ACADEMICALLY

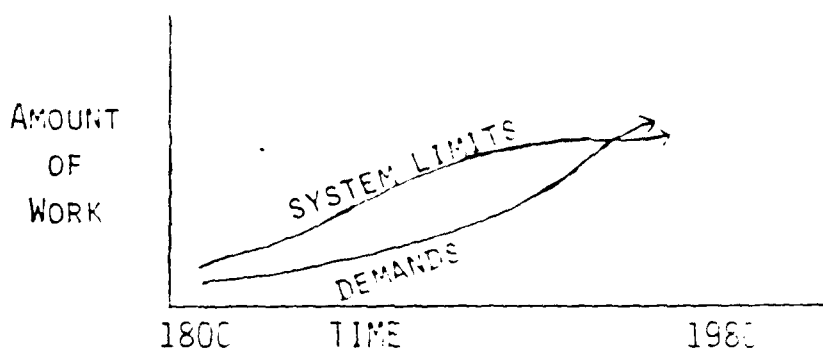
ECONOMIC CHANGES:

- PERSONNEL COSTS, EQUIPMENT AND AMMUNITION COSTS, TRAVEL COSTS, AND ECONOMIC INFLATION MAKE REALISTIC TRAINING MORE DIFFICULT.
- TRAINING TIME HAS BEEN CUT.

- MANY APPROACHES TO THESE PROBLEMS ARE CALLED FOR, BUT IN THE AREA OF TRAINING AND JOB AIDING, "MORE OF THE SAME" ISN'T WORKING.

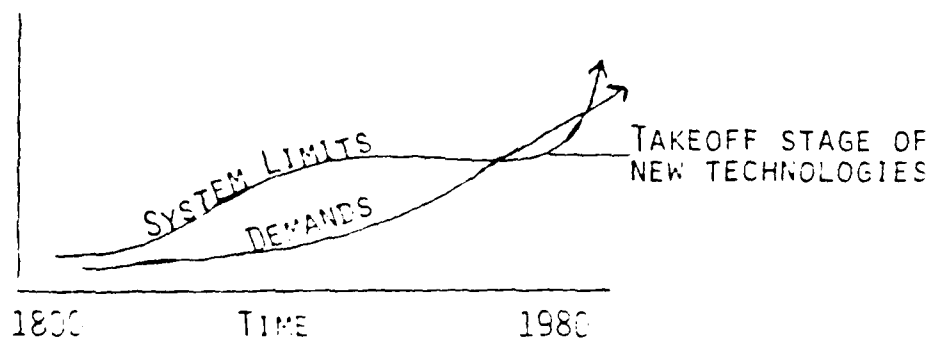
THE PROBLEM (CONTD.)

- THE CURRENT PAPER AND LECTURE DELIVERY SYSTEM HAS NEARED THE LIMITS OF ITS PRODUCTIVE CAPACITY.
 - ONE SYMPTOM: AN ENORMOUS INCREASE IN QUANTITY OF PRINTED MATERIAL.
 - ANOTHER SYMPTOM: UPDATING A MANUAL IN THE FIELD CAN TAKE YEARS.
- BY ANALOGY, THE CURRENT NON-INTERACTIVE PAPER AND LECTURE DELIVERY SYSTEM IS LIKE THE PROPELLER AIRPLANE. FURTHER REFINEMENTS ARE POSSIBLE, BUT WILL NOT PRODUCE MAJOR GAINS. ORDER OF MAGNITUDE INCREASES IN PRODUCTIVITY ARE REQUIRED.
 - WITH AIRCRAFT, AN ENTIRELY DIFFERENT APPROACH TO PROPULSION WAS REQUIRED: THE JET.
 - WITH TRAINING AND JOB AIDING A SIMILAR BREAKTHROUGH IS REQUIRED: INTERACTIVE, ELECTRONIC DELIVERY SYSTEMS.



THE OPPORTUNITY

- HARD TECHNOLOGIES
 - COMPUTER CHIPS
 - OPTICAL MEMORIES
 - SATELLITE AND FIBER OPTIC COMMUNICATION NETWORKS
- SOFT TECHNOLOGIES
 - COMPREHENSIVE TEACHING AND LEARNING MODELS, BASED ON FINDINGS FROM NUMEROUS DISCIPLINES.
 - INCREASED UNDERSTANDING OF THE PROCESSES OF BRINGING ABOUT CHANGE IN ORGANIZATIONS.
- WITH ACTUAL EQUIPMENT COSTS INCREASING, ELECTRONIC DELIVERY SYSTEM COSTS FOR TRAINING AND JOB AIDING MAY BE NEGLIGIBLE.
- AVAILABILITY OF ELECTRONICS AND SOFTWARE UTILITIES FOR TRAINING IS REACHING THE TAKEOFF STAGE, WHERE ONE DEVELOPMENT FUELS THE NEXT.



PURPOSE OF THIS STUDY

QUALITATIVELY ANALYZE THE COST/EFFECTIVENESS FOR
ELECTRONIC DELIVERY SYSTEMS OF:

- COLOR, SHADING, AND GRAY SCALE
- MOTION
- SOUND
- IMAGE QUALITY
- INTERACTION
- OTHER PRESENTATION FEATURES

USE INFORMATION ABOUT THESE FEATURES TO RECOMMEND DISPLAY AND
RESPONSE ALTERNATIVES FOR COMMUNICATIVE ELECTRONIC DELIVERY
SYSTEMS

CRITERIA FOR ELECTRONIC DELIVERY SYSTEMS

EFFECTIVE

- USER COMPREHENSION OF PRESENTED INFORMATION
- RATE OF COMPREHENSION
- RETENTION
- USER ACCEPTANCE AND MOTIVATION

LOW COST

- HARDWARE ACQUISITION
- HARDWARE OWNERSHIP (RELIABILITY, AVAILABILITY, MAINTAINABILITY)
- SOFTWARE AND COURSEWARE DEVELOPMENT
- SOFTWARE AND COURSEWARE UPDATE AND REVISION

HIGH BENEFITS

- SIMPLICITY OF USE
- COMPATIBILITY WITH EXISTING DELIVERY SYSTEMS (E.G., PRINT AND CUE/SEE)
- SMALL SIZE
- RUGGED
- MODULAR, PLUG COMPATIBLE COMPONENTS
- RAPIDLY EXPANDABLE, EASILY REPLICATED FOR FAST RESPONSE TO MOBILIZATION

THE APPROACH USED

- DEFINE HOW THE SYSTEMS WILL BE USED (SCENARIOS)
- DEFINE A CANDIDATE FAMILY OF DELIVERY SYSTEMS WITH MODULAR COMPONENTS TO MEET THESE USAGE REQUIREMENTS
- USING EXISTING RESEARCH AND NEW EXPERIMENTS, DETERMINE THE EFFECTIVENESS AND OTHER BENEFITS OF CANDIDATE FEATURES
- ESTIMATE COSTS FOR QUANTITY PURCHASES IN 1985 TO OBTAIN DIFFERENT FEATURES. EXAMINE COST BENEFIT TRADEOFFS AND RECOMMEND A SET OF PREFERRED FEATURES AND A SET OF LOWEST FEASIBLE COST FEATURES FOR EACH TYPE OF SYSTEM
- MAKE RECOMMENDATIONS FOR FEATURES IN THE CONTEXT OF ACTUAL ALTERNATIVE DISPLAY AND RESPONSE COMPONENTS

THE GOAL AND SOME CONSTRAINTS

- SPECIFY STAND-ALONE ELECTRONIC DELIVERY SYSTEMS FOR TRAINING MATERIALS AND JOB PERFORMANCE AIDS
- USE VIDEO AND COMPUTER TECHNOLOGY (POWER OF BOTH THE AUDIO/VISUAL AND COMPUTER TRADITIONS)
- ANTICIPATE HIGH DENSITY IN THE ARMY
- LOW UNIT COST IS A MAJOR DRIVER OF THE DESIGN
- MAXIMUM EFFECTIVENESS REQUIRED FOR INSTRUCTION AND JOB AIDING
- USER INTERFACE MUST BE EXCELLENT

HOW THE SYSTEMS WILL BE USED

1. ON THE JOB TRAINING:
 - TRAINING EXTENSION COURSE (TEC) LESSONS
 - SKILL QUALIFICATION TESTS (SQT)
 - ARMY TRAINING AND EVALUATION PROGRAM (ARTEP)
 - JOB TRAINING PACKAGES (JTP)
2. SKILL PERFORMANCE AIDS (SPA)
3. TRADOC SCHOOLS (INCLUDING SIMULATION)
4. RECRUITING
5. ARMED FORCES ENTRANCE AND EXAMINATION STATIONS (AFEES)
6. ELECTRONIC OFFICES

WHEN ANALYZED, THE USES REQUIRED FIVE MAJOR TYPES OF SYSTEMS FOR:

- INSTRUCTION IN A SHELTERED ENVIRONMENT
- COMMAND MANAGEMENT AND ADMINISTRATION IN A SHELTERED ENVIRONMENT
- JOB AIDS IN THE FIELD
- AUTHORIZING
- RATING AND INVENTORY USING A HAND HELD DEVICE IN THE FIELD

THESE CAN BE SUPPORTED BY ON-SITE UTILITIES LIKE A PRINTER, HIGH CAPACITY SHARED MEMORY, AND MODEMS.

EFFECTIVENESS AND OTHER BENEFITS OF CANDIDATE FEATURES

COLOR, SHADING, AND GRAY SCALE

- COLOR CAN INCREASE BOTH IMMEDIATE PERFORMANCE AND RETENTION IN COMPARISON TO A MONOCHROME PRESENTATION .
- LEARNERS APPEAR TO TAKE MORE TIME ASSIMILATING COLOR INFORMATION THAN MONOCHROME.
- THE ABOVE MAY EXPLAIN WHY AVAILABLE RESEARCH INDICATES THAT COLOR HAS NO CONSISTENT EFFECT ACROSS ALL LEARNING SITUATIONS: COLOR IS BETTER FOR SELF-PACED MATERIALS BUT NOT FOR FIXED PAGED, FOR STILLS BUT NOT FOR MOTION, AND FOR HIGH APTITUDE LEARNERS BUT NOT FOR LOW APTITUDE.
 - LEARNERS MUST BE GIVEN SUFFICIENT TIME TO ASSIMILATE COLOR. IF THEY ARE, PERFORMANCE IS USUALLY BETTER THAN WITH MONOCHROME. IF THEY ARE NOT GIVEN SUFFICIENT TIME, PERFORMANCE APPEARS TO BE WORSE.
 - OVERALL, THE RATE OF ACHIEVEMENT GAIN OVER TIME IS EQUIVALENT BETWEEN COLOR AND MONOCHROME.
- COLOR IS REQUIRED WHEN THE TASK DEMANDS COLOR DISCRIMINATIONS.
- COLOR CODING IS VERY PRODUCTIVE FOR HIGHLIGHTING AND DISTINGUISHING PORTIONS OF DISPLAYS (E.G. ONE LEVEL OF DEPTH IN A 3D GRAPHIC) OR TYPE OF CONTENT (E.G., A SET OF RULES).

EFFECTIVENESS AND OTHER BENEFITS OF CANDIDATE FEATURES (Contd.)

- COLOR VIDEO CAPABILITY PERMITS USE OF EXISTING COLOR MATERIALS, USUALLY WITHOUT REFORMATTING (E.G., TEC, ETV).
- MOST STUDENTS TODAY EXPECT COLOR AND PREFER IT OVER MONOCHROME. IT MAY THUS HAVE A MOTIVATIONAL ADVANTAGE WHICH CAN DECREASE ATTRITION.
- FOR SPA'S, EXISTING PRINTED MATERIALS CAN BE REFORMATTED WITH COMPUTER-GENERATED ALPHANUMERICS AND LINE GRAPHICS. FUTURE SPA'S CAN BE PRODUCED INITIALLY THIS WAY, USING COMPUTER DESIGN AND EDITING AIDS.
- IF GRAY SCALE IS USED IN COMPUTER GENERATED DISPLAYS, FOUR LEVELS ARE THE MOST REQUIRED, AND USUALLY TWO OR THREE LEVELS WILL SUFFICE.

MOTION

- THE AVAILABLE RESEARCH STUDIES INDICATE THAT THE EFFECT OF MOTION DEPENDS ON THE PURPOSE, THE CONTENT, AND OTHER FACTORS.
- PROCEDURES INVOLVING A CRITICAL DEMONSTRATION OF ACTIONS OVER TIME ARE BEST PRESENTED WITH MOTION. SPATIAL CONCEPTS ARE BEST PRESENTED WITH STILLS.
- HUMAN MODELING TO CHANGE ATTITUDES OFTEN REQUIRES MOTION.
- MOTION CAPABILITY PERMITS USE OF EXISTING MOTION MATERIALS. IT IS EASY TO TRANSFER FROM 16 MM FILM OR FROM VIDEO TO VIDEODISC.
- MOTION SEQUENCES TYPICALLY DO NOT ALLOW SELF PACING. CARE MUST BE TAKEN NOT TO PRESENT INFORMATION SO FAST THAT THE LEARNER CANNOT PROCESS IT WELL. SPEED SHOULD BE SLOWED DOWN OR UNDER USER CONTROL TO DEMONSTRATE MOTOR SKILLS.
- A HIGH PROPORTION OF MOTION IN EXISTING FILMS IS NON-RELEVANT (STILLS).
- STILLS WITH AUDIO ARE OFTEN AS EFFECTIVE AS MOTION WITH AUDIO.
- ANIMATED GRAPHICS CAN HELP TO VISUALIZE AND CLARIFY PROCESSES OF MANY KINDS, AND ARE ESPECIALLY USEFUL IN SIMULATIONS.

REALISM

- REALISM MUST BE MATCHED TO THE LEARNER'S EXPERIENCE.
 - THE LEARNER WHO IS NEW TO A SUBJECT NEEDS SIMPLIFIED PRESENTATIONS (E.G., LINE DRAWINGS). MORE EXPERIENCED INDIVIDUALS NEED A REPLICA OF THE COMPLEXITY OF THE ACTUAL SITUATION.
 - OPTIMAL REALISM MAY CHANGE AS THE LEARNER GROWS MORE PROFICIENT.
 - TOO MUCH DETAIL AT FIRST CAN IMPEDE LEARNING BY OBSCURING THE CRITICAL POINTS.
 - TOO LITTLE DETAIL FOR PERSONS EXPERIENCED IN THE CONTENT MAY NOT GIVE THEM REAL WORLD EXPERIENCE IN FINDING THE CRITICAL FEATURES ON THEIR OWN.

- REALISM MUST BE MATCHED TO THE METHOD OF PRESENTATION.
 - STUDENTS NEED TIME TO PROCESS COMPLEX VISUALS.
 - REALISTIC DRAWINGS AND PHOTOGRAPHS ARE MOST EFFECTIVE FOR SELF PACED INSTRUCTION (LIKE THAT AVAILABLE ON ELECTRONIC DELIVERY SYSTEMS), WHERE THE STUDENT CAN STUDY THE MATERIALS AS LONG AS NEEDED.
 - SIMPLE LINE DRAWINGS ARE BEST FOR EXTERNALLY PACED INSTRUCTION (LIKE VIDEOTAPE), WHERE SUFFICIENT TIME MAY NOT BE AVAILABLE FOR ALL STUDENTS TO PROCESS THE INFORMATION.

- THE FUNCTIONALITY OF THE PRESENTATION, NOT ITS REPLICA NATURE IS WHAT COUNTS.

REALISM (CONTD.)

- A SEQUENCE OF INCREASINGLY REALISTIC, COMPLEX, OR DIFFICULT EXPERIENCES MAY BE OPTIMAL.
--AN EXAMPLE IS USE OF THE GRADUATED LENGTH METHOD IN SKIING, WHERE THE LEARNER PROGRESSES FROM SIMPLE TO USE SHORT SKIS TO REGULAR LENGTH SKIS AND STEEPER HILLS.
- PICTORIAL REALISM WITH COLOR AND MOTION IS USUALLY PREFERRED BY STUDENTS.
- PICTURES CAN FACILITATE LEARNING FROM TEXT.
- MULTIMEDIA PRESENTATIONS MAY REDUCE ATTRITION BY MAINTAINING STUDENT INTEREST.
--CAUTION: A MOTIVATIONAL LEARNING EXPERIENCE FOLLOWED BY A BORING JOB WILL NOT REDUCE TURNOVER.

IMAGE QUALITY - "GRAININESS"

- CHARACTER RESOLUTION - 10 TO 12 TV SCAN LINES PER CHARACTER. FOR TECHNICAL MANUALS THE US BROADCAST STANDARD IS INSUFFICIENT AS INVESTIGATED IN EXPERIMENT 3 OF THIS STUDY. IN EXPERIMENT 4 WE FOUND THAT AROUND 945 SCAN LINES ARE REQUIRED AT 20 MHZ (BLACK AND WHITE) TO PRESENT A FULL PAGE OF TEXT AND GRAPHICS ON THE SCREEN. THE US BROADCAST STANDARD IS 525 SCAN LINES WITH APPROXIMATELY 4.2 MHZ. USING THE US STANDARD, 12 LINES OF 30 CHARACTERS IS PREFERRED, THOUGH MORE CAN BE PUT ON THE SCREEN.
- VIEWING DISTANCE - USUALLY 28 TO 38 INCHES IS PREFERRED. THE VIEWER MUST BE WITHIN TOUCHING DISTANCE (ABOUT 21 INCHES) IF A TOUCH SCREEN IS USED.
- GRAY SCALE LEVELS - FOUR LEVELS OF GRAY IS THE MOST THAT IS USUALLY NEEDED AND 2 OR 3 LEVELS ARE ADEQUATE FOR ALPHANUMERICS AND MANY GRAPHICS.
- CHARACTER SIZE - APPROXIMATELY .2 INCH PER CHARACTER, VIEWED AT 28 INCHES (=15 TO 30 MIN. OF ARC). CHARACTER SIZE SHOULD BE DETERMINED BY CONTENT BEYOND THIS BASIC RECOMMENDATION.

IMAGE QUALITY - "GRAININESS" (CONT'D.)

- FONT - NO ESTABLISHED SUPERIORITY OF ANY FONT FOR CRT'S, BUT LINCOLN/MITRE, MIL-M-10812, AND LEROY FONTS ARE ALL ACCEPTABLE. ON A VIDEO DISPLAY A STUDIO QUALITY CHARACTER GENERATOR CAN PRODUCE A VERY WIDE VARIETY OF FONTS TO MATCH THE CONTENT AND STYLE.
- DOT MATRIX SIZE OF CRT CHARACTERS - 5x7 DOTS MINIMUM, 7x9 PREFERRED FOR EACH CHARACTER.
- COLOR OF MONOCHROME DISPLAY - IS NOT A MAJOR FACTOR. BLACK/WHITE, YELLOW, GREEN ARE ALL ACCEPTABLE.
- UPPER CASE VS. UPPER AND LOWER CASE - DATA FOR CRT'S IS THIN, BUT MIXED UPPER AND LOWER CASE IS BETTER FOR PRINTED TEXT OF LENGTHY PASSAGES.

IMAGE QUALITY - VISUAL ELEMENTS

- MEANINGFULNESS OF VISUAL ELEMENTS IS MORE IMPORTANT THAN REALISM--HAND SKETCHED LINE DRAWINGS WHICH HIGHLIGHT CRITICAL POINTS CAN BE AS EFFECTIVE AS DETAILED COLORED PICTURES.
- FOR PROCEDURAL INSTRUCTION, TEXT PLUS ILLUSTRATIONS IS BETTER THAN EITHER BY ITSELF.
- USERS DIFFER IN VISUAL LITERACY. COMPLEX CHARTS AND GRAPHS REQUIRE MORE EXPERIENCE THAN SIMPLE PICTURES, SO VISUAL ELEMENTS MUST BE MATCHED TO USER ABILITIES AND EXPERIENCE.
- EXPERIMENT 1 IN THIS STUDY FOUND THAT LINE DRAWINGS YIELDED RESULTS EQUAL TO PHOTOGRAPHS, NOT ONLY FOR PAPER AND PENCIL TESTS, BUT ALSO FOR JOB PERFORMANCE TESTS.

SOUND PRESENTATIONS

- REALISTIC VOICE OR OTHER SOUNDS ARE REQUIRED FOR MANY KINDS OF MODELING, WHERE THE OBJECTIVE IS TO CHANGE ATTITUDES OR ILLUSTRATE A PROCEDURE BY PRESENTING AN EXPERT.
- SOUNDS ARE REQUIRED TO MAKE CERTAIN DISCRIMINATIONS (E.G., BETWEEN A MOTOR RUNNING SMOOTHLY OR ROUGHLY).
- NON-VOICE SOUNDS (E.G., PENNY ARCADE GAMES) CAN ADD EXCITEMENT AND MOTIVATION TO SIMULATIONS.
- SYNTHESIZED AND DIGITIZED SPEECH VARIES WIDELY IN QUALITY. LOW QUALITY IS APPROPRIATE FOR CUEING AND PRESENTING WORDS IN CONTEXT (SINCE A WORD IN A PHRASE IS EASIER TO UNDERSTAND THAN A WORD IN ISOLATION). HIGHER QUALITY IS REQUIRED FOR ISOLATED WORDS OR WHERE UNDERSTANDING IS CRITICAL.
- PERMITS COMMUNICATION WHEN THE USER IS AWAY FROM THE TERMINAL OR LOOKING ELSEWHERE (E.G., AT A SIMULATOR OR WHILE FIXING SOMETHING).
- AUDIO IS HELPFUL TO POOR READERS, AND AUDIO REDUNDANT WITH TEXT IS PREFERRED BY SOME WHO CAN READ.
- EXTENSIVE VOICE PRESENTATION SLOWS DOWN AND PACES THE MAN/MACHINE INTERACTION. THIS MAY OR MAY NOT BE HELPFUL.

INTERACTION - PROCESSES

- THE BULK OF ELECTRONIC DELIVERY SYSTEMS INTERACTIONS FOR MOST APPLICATIONS CONSISTS OF A SIMPLE PROMPT OR QUESTION, AND A STUDENT RESPONSE.
- AN ENORMOUS VARIETY OF INTERACTIONS, FROM SIMPLE MENU AND MULTIPLE-CHOICE BRANCHING TO FAIRLY COMPLEX INFORMATION SEARCHES, JOB AIDS, GAMES, AND SIMULATIONS CAN BE PROGRAMMED FROM A LIMITED, SIMPLE SET OF COMMANDS AND DATA STRUCTURES.
- AS THE PROGRAM BECOMES MORE ARTIFICIALLY INTELLIGENT, FOUR ELEMENTS BECOME MORE SOPHISTICATED:
 - AN INTERACTIVE MODEL OF THE CONTENT BEING TAUGHT (E.G., A PIECE OF EQUIPMENT BEING SIMULATED)
 - A MODEL OF AN EXPERT WHO OPERATES THE SYSTEM (E.G., A PROCEDURE FOR SOLVING A PROBLEM)
 - A MODEL OF EACH STUDENT (RANGES FROM A HISTORY OF STUDENT'S KEYPRESSES TO A SOPHISTICATED MODEL OF SPECIFIC SKILLS)
 - AN ADVISOR TO MAKE COMMENTS OR PRESENT PROBLEMS THAT WILL MOVE THE STUDENT PERFORMANCE CLOSER TO THAT OF THE EXPERT
- IN A CLASSROOM, THE SUBJECT MATTER IS THE CONTENT MODEL; THE TEXT, OR TECHNICAL MANUAL HOLDS THE EXPERT MODEL; THE INSTRUCTOR IS BOTH AN EXPERT AND THE ADVISOR; AND THE GRADE BOOK CONTAINS THE STUDENT MODEL. THE VIDEO MATERIALS AND COMPUTER PROGRAM CAN SERVE ALL OF THESE FUNCTIONS IN AN ELECTRONIC DELIVERY SYSTEM, AT DIFFERENT LEVELS OF COST AND SOPHISTICATION.
- THE DATA FROM EXPERIMENT 2 OF THIS STUDY SUGGESTS THAT JOB AIDS MAY YIELD ACCURACY AND TIME RESULTS EQUIVALENT TO OF BETTER THAN SEPARATE INSTRUCTION FOLLOWED BY ACCESS TO TECHNICAL MANUALS. SIMPLICITY CAN THUS YIELD MAJOR BENEFITS.

INTERACTION - PROCESSES (CONTD.)

- AN ELECTRONIC DELIVERY SYSTEM MAY BE USED IN SEVERAL INTERACTION MODES:

(1) PRESENTATION MODE

- ALLOWS NON-INTERACTIVE PAGES OF TEXT OR MOTION SEGMENTS TO BE PRESENTED WITH ACCOMPANYING AUDIO OR ILLUSTRATIONS IN ANY COMBINATION.
- THE USER CONTROLS RATE AND SOMETIMES SEQUENCE.
- ESSENTIALLY THIS IS A PAGE TURNING MODE WHICH MAY PRESENT AN EXPERT PROCEDURE.

(2) EXERCISE MODE

- USERS RESPOND TO STORED QUESTIONS OR PROBLEMS, AND RECEIVE IMMEDIATE FEEDBACK.
- BRANCHING DEPENDS ON THE ANSWERS.
- WITHOUT TWO SCREENS OR TEXT/GRAPHICS OVERLAY, MOST VIDEODISC SYSTEMS STOP WITH THIS MODE.
- THE EXPERT, STUDENT MODEL, AND ADVISOR FUNCTIONS MAY BE INCLUDED.
- SOME SIMULATIONS FOR FIXED SEQUENCE PROCEDURES USE THIS MODE, SINCE THEY ARE JUST A FIXED SEQUENCE OF ACTIONS.

(3) GENERATIVE SIMULATION MODE

- INTRODUCES A PARTIAL MODEL OF THE SYSTEM, WHICH PERMITS NEW ITEMS TO BE GENERATED.
- PROVIDES REALISTIC EXERCISE OF CONCEPTS AND RULES WHILE MAINTAINING TEST INTEGRITY (SINCE EVALUATION TYPICALLY OCCURS WITH UNIQUE EXEMPLARS).

INTERACTION - PROCESSES (CONT'D.)

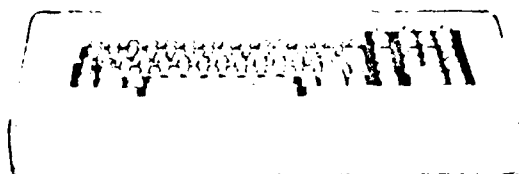
--EXAMPLES ARE (A) GENERATION OF MATHEMATICS PROBLEMS FOR DRILL IN ADDITION AND SUBTRACTION OR (B) ELECTRONIC EQUIPMENT TROUBLESHOOTING TRAINERS.

--USER INTERACTIONS CAN BE MORE EXTENSIVE, SINCE NEW EXERCISES CAN BE PRODUCED TO FIT INDIVIDUAL NEEDS. THE EXPERT, STUDENT MODEL, AND ADVISOR FUNCTIONS MAY ALL BE INCLUDED.

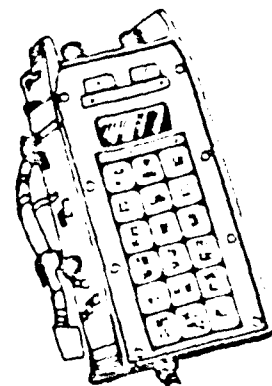
- IN EXERCISE AND GENERATIVE MODES, STUDENT INTERACTIONS CAN BECOME COMPLEX--RANGING FROM ENTERING DATA TO FLYING A SIMULATED AIRCRAFT.

INTERACTION - MECHANISMS

- A HIGH PROPORTION OF POTENTIAL USERS OF ELECTRONIC DELIVERY SYSTEMS DO NOT TYPE WELL.
- STANDARD ALPHANUMERIC KEYBOARDS
 - GOOD FOR TYPISTS WHERE A HIGH VOLUME OF ALPHANUMERICS MUST BE ENTERED.
 - NOT EFFICIENT FOR MOST SOLDIERS AND NCO'S.



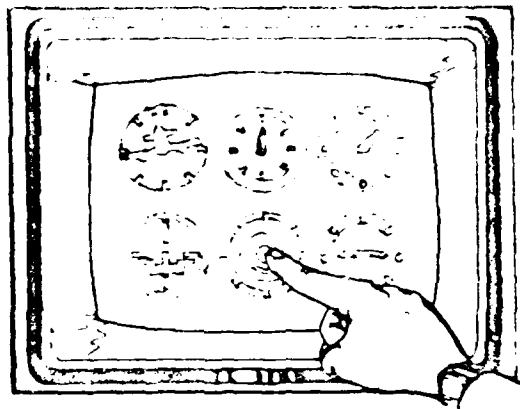
- KEYPADS
 - MORE EFFICIENT THAN KEYBOARDS FOR MANY TRAINING APPLICATIONS.
 - CAN BE VERY INEXPENSIVE, BUT MUST USUALLY BE CONFIGURED FOR A SPECIFIC APPLICATION.
 - THEY LIMIT THE TYPE OF RESPONSES WHICH CAN BE ENTERED AND MAKE NON-NUMERIC PROBLEMS INTO MULTIPLE CHOICE, SINCE ALL THE POSSIBLE RESPONSES ARE DISPLAYED ON THE KEYPAD.
 - IF USED TO SELECT AMONG FUNCTIONS (E.G., NEXT) WHERE ANOTHER DEVICE (E.G., A MOUSE) IS USED FOR INPUTTING RESPONSES, THEY CAN BE VERY EFFICIENT.



INTERACTION - MECHANISMS (CONTD.)

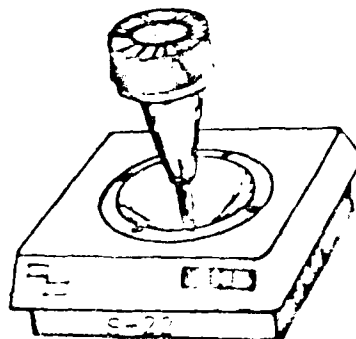
- TOUCH PANELS

- NATURAL, NO TRAINING REQUIRED.
- CAN ALTER THE RESPONSE CHOICES, BY CHANGING DISPLAYS ON THE SCREEN.
- USER MUST BE CLOSER THAN IS NORMALLY PREFERRED, AND REPEATED REACHING UP TO TOUCH CAN BE TIRING.
- PREFERRED OVER LESS RELIABLE LIGHT PENS, WHICH REQUIRE A BRIGHT SPOT AS A TARGET.



- JOY STICKS

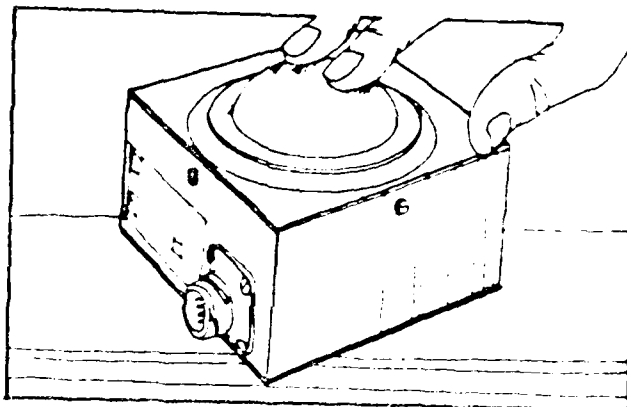
- INEXPENSIVE AND FREQUENTLY USED.
- PROVIDES FUNCTIONS OF TOUCH PANELS, PLUS SOME ADDITIONAL FUNCTIONS.
- ALLOWS CURSOR MOVEMENT AND POSITIONING ON SCREEN. FUNCTION BUTTON OR KEY PAD NEEDED TO INDICATE CHOICE.
- INFERIOR TO TRACKBALL OR MOUSE FOR CONTINUOUS CURSOR MOVEMENT.



INTERACTION - MECHANISMS (CONTD.)

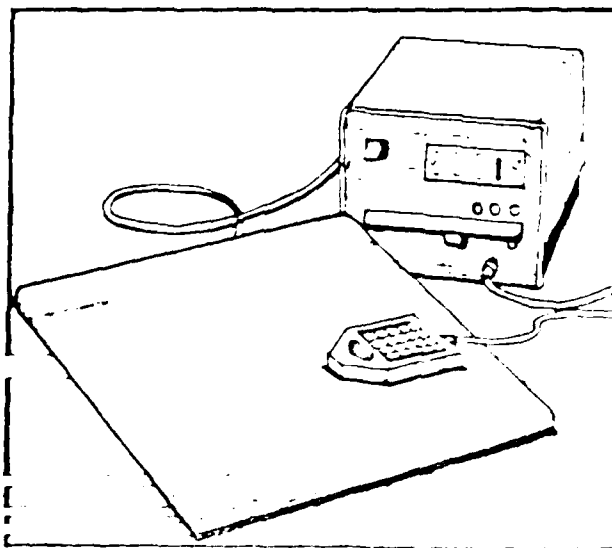
- TRACKBALLS

- MORE EXPENSIVE THAN JOYSTICK.
- ALLOWS INFINITE MOTION BY CONTINUING TO TURN THE BALL.
- NEEDS FUNCTION KEY.



- MOUSE AND GRAPHICS TABLET

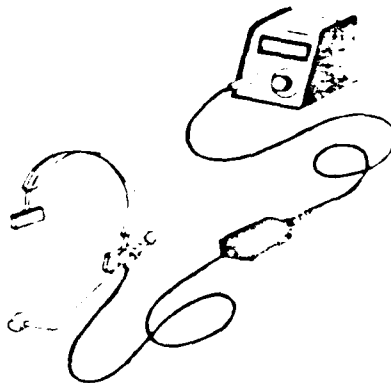
- CAN MOVE CURSOR ON SCREEN WITH ONE HAND.
- LIKE A TOUCH PANEL TAKEN OFF THE SCREEN.
- NEEDS FUNCTION KEY OR KEYS.
- AVOIDS FATIGUE OF REACHING FOR SCREEN, BUT REQUIRES A LITTLE EXPERIENCE.
- GRAPHICS TABLET USED FOR HIGH RESOLUTION DIGITIZING OF GRAPHICS, WHILE MOUSE PROVIDES RAPID CURSOR POSITIONING FOR INTERACTIONS.



INTERACTION - MECHANISMS (CONTD.)

• VOICE INPUT

- USED WHERE HANDS OR EYES ARE BUSY (E.G., FOR MAINTENANCE AIDING).
- A NATURAL MEANS OF COMMUNICATION FOR NON-TYPIST SOLDIERS.
- AVOIDS TYPING. HIGH QUALITY UNITS ARE MORE ACCURATE THAN TYPING ONCE THE SYSTEM HAS LEARNED THE USER'S VOICE.
- PERMITS MOBILITY.
- GOOD QUALITY UNITS ARE STILL EXPENSIVE, BUT SHOULD DECREASE IN PRICE BY 1985.
- DISADVANTAGES: A BRIEF PAUSE MUST SEPARATE EACH WORD OR ITEM. EACH USER MUST TRAIN THE SYSTEM FOR EACH UTTERANCE TO BE RECOGNIZED. CAN BE MORE TIRING THAN TYPING FOR HIGH VOLUMES OF DATA ENTRY.
- SINCE ALTERNATIVES NEED NOT BE PRESENTED ON A SCREEN OR PAD, VOICE INPUT DOES NOT LIMIT INTERACTIONS TO MULTIPLE CHOICE. IT IS THUS MORE FLEXIBLE THAN KEYPADS OR TOUCH-SCREEN.



COST METHODOLOGY

- START WITH 1981 HIGH VOLUME (5,000 UNITS) ORIGINAL EQUIPMENT MANUFACTURER (OEM) PRICE WHERE ONE IS KNOWN.
- DETERMINE RANGE OF PROJECTED PRICES IN 1985 BY APPLYING AN EXPERIENCE CURVE BASED ON THE TYPE OF TECHNOLOGY AND THE CURRENT AND PROJECTED SALES VOLUME. CONVERT THIS TO PROJECTED YEARLY DECREASES IN COST. GENERALLY AS CUMULATIVE VOLUME DOUBLES, PRICE IN REAL TERMS IS CUT BY 20 TO 30 PERCENT.
- SELECT THE PROBABLE PRICE WITHIN THE RANGE BY INTERVIEWING EXPERTS. THIS YIELDS A ROUGH PRICE ESTIMATE.
- THESE PRICES ARE SUGGESTIVE OF COMPONENT PRICES ONLY. IN SOME CASES (E.G., KEYBOARDS) THE COMPONENTS SIMPLY PLUG IN TO THE BASIC SYSTEM. IN OTHER CASES (E.G., TOUCH PANELS) PROGRAMMING MAY BE REQUIRED. COSTS OF INTEGRATION, CHECKOUT, DELIVERY, ETC. MIGHT AVERAGE 20 PERCENT PER SYSTEM.
- PROJECTED PRICES ARE IN TERMS OF 1981 DOLLARS. THUS INFLATION MUST BE ADDED TO THESE FIGURES TO ARRIVE AT NOMINAL 1985 PRICES. THE FIGURES PRESENTED HERE ARE SIMPLY DISCUSSION POINTS. THE TECHNICAL DATA BASE CORRELATION STUDY WILL REVIEW AND REFINE THESE FIGURES.

RECOMMENDED BASIC SYSTEM COMPONENTS

(NOT FOR HAND-HELD UNITS)

PROCESSING

PROJECTED GEN
PRICE IN 1972

PREFERRED

32 BIT MILITARY COMPUTER FAMILY CENTRAL PROCESSING UNIT (CPU) IN WORKING SYSTEM (I.E., INCLUDES POWER SUPPLY, BUS, PORTS, ETC.)	\$ 520
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256K RANDOM ACCESS MEMORY (RAM) MINIMUM	\$ 300
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OPTIONAL

MILITARIZED 32 BIT CPU FOR USE IN FIELD	\$1040
MILITARIZED 256K RAM FOR USE IN FIELD	\$ 600

MINIMUM COST

16 BIT COMMERCIAL MICROPROCESSOR	\$ 210
AND 256K RAM (MINIMUM)	\$ 300

LANGUAGES

ADA
FORTRAN
PASCAL
BASIC
C

SYSTEM SHOULD SUPPORT STANDARD
VERSIONS OF THESE LANGUAGES SO
EXISTING SOFTWARE CAN BE USED.
LANGUAGES NEED NOT BE AVAILABLE
SIMULTANEOUSLY.

STORAGE

PREFERRED

CONNECTION TO ON-SITE SHARED STORAGE CONSISTING OF WINCHESTER DISK AND CONTROLLER (30 MEGABYTES) WITH TAPE BACKUP (CARTRIDGE) AND CONTROLLER, SHARED BY FOUR USERS. PRICE IS PER USER. \$ 650

OPTION

ID CARD READER/WRITER \$ 75
OR MILITARIZED SOLID STATE 1 MEGABYTE MEMORY FOR USE IN FIELD. \$145
OR DEDICATED 10 MEGYTE WINCHESTER DISK WITH TAPE CASSETTE BACKUP AND CONTROLLERS FOR STAND-ALONE SYSTEM. \$100

MINIMUM COST

DUAL SIDED DOUBLE DENSITY FLOPPY DISK (2 MEGYTE) WITH CONTROLLER. \$ 400

SOFTWARE/USER UTILITIES

PREFERRED

DATA BASE MANAGEMENT SYSTEM
AND REPORT GENERATOR
AND ELECTRONIC MAIL
AND WORD PROCESSING
AND SORT/MERGE
FREE WITH VERY LARGE HARDWARE QUANTITIES.

RECOMMENDED FEATURES FOR EACH SYSTEM TYPE

A. INSTRUCTION IN A SHELTERED ENVIRONMENT

RESPONSE

PROJECTED NEW
PRICE IN 1977

PREFERRED

KEYPAD
AND TOUCH PANEL

\$ 15
\$ 50

OPTIONS

HIGH QUALITY VOICE INPUT
OR KEYBOARD
OR LOW RESOLUTION JOYSTICK
OR LOW RESOLUTION MOUSE
OR VALUATOR (E.G., RHEOSTAT)
OR TRACKBALL

\$ 350
\$ 50
\$ 25
\$ 50
\$ 25
\$ 150

DISPLAY

PREFERRED

13" MED. RESOLUTION (E.G., 512X512 PIXEL) COLOR GRAPHICS TERMINAL WITH NTSC VIDEO CAPABILITY
AND NTSC INDUSTRIAL VIDEODISC PLAYER \$ 800
AND VIDEODISC INTERFACE FOR CONTROL ONLY \$ 100
OR LOW TO MEDIUM RESOLUTION (E.G., 300X400 PIXELS) MONOCHROME TERMINAL WITH TEXT/GRAPHICS \$1000

OPTIONS

PROJECTION SYSTEM FOR LARGE AUDIENCES FOR NTSC COLOR \$2200
OR DIGITIZED RANDOM ACCESS VOICE OUTPUT \$ 650

MINIMUM COST VIDEO

NTSC USA BROADCAST STANDARD COLOR MONITOR \$ 300
AND NTSC TEXT/GRAPHICS CHARACTER GENERATOR \$ 200

COST SUMMARY

A. INSTRUCTION IN A SHELTERED ENVIRONMENT

PREFERRED

32 BIT CPU	\$ 520
256K RAM	250
1/4 SHARE OF	
30 MBYTE DISK/TAPE	650
KEYPAD	15
TOUCH PANEL	50
512X512 COLOR	3000
GRAPHICS/TERMIN.	
WITH NTSC VIDEO	
NTSC VDISC PLAYER	800
VDISC CONTROLLER	100
	<u>5425</u>

INTEGRATION, ETC	1085
(20%)	
	<u>\$6510</u>

ALL DIGITAL OPTION

32 BIT CPL	\$ 520
256K RAM	250
1/4 OF 30 MBYTE	650
DISK/TAPE	
KEYPAD	15
TOUCH PANEL	50
300X400 MONOCHROME	
GRAPHICS TERMIN.	1000
	<u>2525</u>

INTEGRATION (20%)	505
	<u>\$3030</u>

MINIMUM COST VIDEO

16 BIT CPU	\$ 200
256K RAM	250
2 MBYTE FLOPPY	100
KEYPAD	15
TOUCH PANEL	50
NTSC MONITOR	200
NTSC VIDEODISC	
PLAYER	800
NTSC CHAR. GEN	200
VDISC CONTROLLER	100
	<u>2375</u>

INTEGRATION (20%)	475
	<u>\$2850</u>

E. ADMINISTRATION MANAGEMENT IN A SIMULATED ENVIRONMENT RESPONSE

PREFERRED

KEYBOARD \$ 70

OPTIONS

TOUCH PANEL	\$ 50
OR COMMERCIAL QUALITY VOICE INPUT	\$ 300
OR KEYPAD	\$ 15
OR LOW RESOLUTION JOYSTICK	\$ 25

PROJECTED PER
CENTAGE IN 1982

DISPLAY

PREFERRED

MEDIUM RESOLUTION (512x512) COLOR CRT \$3000
W/MED. RESOLUTION TEXT/GRAPHICS GENERATOR

MINIMUM COST

LOW TO MEDIUM RESOLUTION (E.G., 400x300) \$1000
MONOCHROME CRT

COST SUMMARY

B. ADMINISTRATION/ MANAGEMENT IN A SHELTERED ENVIRONMENT

PREFERRED

32 BIT CPU	\$ 520
256K RAM	290
1/4 SHARE OF 30	600
1MBYTE DISK/TAPE	70
KEYBOARD	300
512X512 COLOR	4480
TERMINAL	890
INTEGRATION	
(20%)	
	<u>\$5376</u>

MINIMUM COST

16 BIT CPU	\$ 210
256K RAM	290
2 MBYTE FLOPPY	400
KEYBOARD	70
320X240 MONOCHROME	1000
TERMINAL	1970
INTEGRATION	390
(20%)	
	<u>\$2360</u>

C. JOB AIDING IN THE FIELD

RESPONSE

PREFERRED

MILITARIZED KEYPAD \$ 90

OPTIONAL

	MILITARIZED KEYBOARD	\$ 600
OR	MILITARIZED TOUCH PANEL	\$ 375
OR	MILITARIZED HIGH QUALITY VOICE INPUT	\$1700

DISPLAY

PREFERRED

MILITARIZED FLAT PANEL \$3000

OPTIONAL

MILITARIZED VOICE/SOUND OUTPUT \$1300

COST SUMMARY

C. JOB AIDING IN THE FIELD

PREFERRED		MINIMUM COST	
MILITARIZED 32 BIT CPU	\$1040	MILITARIZED 16 BIT CPU	\$ 730
MILITARIZED 256K RAM	580	MILITARIZED 256K RAM	550
MILITARIZED 1 MBYTE SOLID	1425	MILITARIZED 1 MBYTE SOLID	1425
STATE MEMORY		STATE MEMORY	
MILITARIZED KEYPAD	90	MILITARIZED KEYPAD	90
MILITARIZED VOICE INPUT	1700		
MILITARIZED FLAT PANEL	3000	MILITARIZED FLAT PANEL	3000
	7835		5825
INTEGRATION (20%)	1567	INTEGRATION (20%)	1165
	<u>\$9402</u>		<u>\$8990</u>

D. AUTHORIZING

RESPONSE

PROJECTED OEV
PRICE IN 1985

PREFERRED

KEYBOARD	\$ 70
AND HI RESOLUTION GRAPHICS TABLET	\$ 450
AND KEYPAD	\$ 15
AND TOUCH PANEL	\$ 50
AND VALUATOR	\$ 20

OPTIONS

HIGH QUALITY VOICE INPUT	\$ 850
HI RESOLUTION JOYSTICK	\$ 200
HI RESOLUTION TRACKBALL	\$ 200

DISPLAY

PREFERRED

MED RESOLUTION (512x512 PIXELS) COLOR TEXT/GRAPHICS TERMINAL WITH NTSC VIDEO	\$3000
AND NTSC INDUSTRIAL VIDEODISC PLAYER	\$ 800
AND STUDIO QUALITY COLOR TEXT/GRAPHICS CHARACTER GENERATOR	\$60,000
AND 3/4" VIDEOTAPE EDITOR	\$5000

OPTIONS

DIGITIZED RANDOM ACCESS VOICE OUTPUT	\$ 650
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MINIMUM COST

LOW TO MEDIUM RESOLUTION (E.G. 300x400 PIXELS) MONOCHROME MONITOR WITH TEXT/GRAPHICS	\$1000
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AUTHORIZING SOFTWARE

PREFERRED

TEXT/GRAPHICS EDITORS	
AND AUTHORIZING SYSTEM PROTOTYPES TO PREPARE LESSONS BY "FILLING IN THE BLANKS."	
AND AUTHOR MANAGEMENT SYSTEM TO TRACK PRODUCTION AND SCHEDULES.	
AND DATA BASE MANAGEMENT SYSTEM TAILORED TO EVALUATION DATA	

COST SUMMARY

D. AUTHORIZING

PREFERRED

32 BIT CPU	\$ 520
256K RAM	290
KEYBOARD	70
HI RESOLUTION GRAPHICS	450
TABLET	
KEYPAD	15
TOUCH PANEL	50
VALUATOR	20
MEDIUM RESOLUTION	3000
(512x512 PIXELS)	
COLOR GRAPHICS TERM-	
INAL W/NTSC VIDEO	
NTSC INDUSTRIAL	800
VIDEODISC PLAYER	
VIDEODISC CONTROL INTER-	100
FACE	
	<u>\$5315</u>
INTEGRATION (20%)	<u>1063</u>
	<u>\$6378</u>

ALL DIGITAL

32 BIT CPU	\$ 520
256K RAM	290
KEYBOARD	70
HI RESOLUTION GRAPHICS	450
TABLET	
KEYPAD	15
TOUCH PANEL	50
VALUATOR	20
LOW TO MEDIUM RESOLUTION	
(E.G., 300x400	1000
PIXELS) MONOCHROME	
MONITOR W/TEXT/GRAPHICS	
	<u>\$2425</u>
INTEGRATION (20%)	<u>483</u>
	<u>\$2898</u>

STUDIO QUALITY COLOR TEXT/GRAPHICS	
CHARACTER GENERATOR	\$60,000
3/4" VIDEOTAPE EDITOR	3,500

E. RATING AND INVENTORY IN THE FIELD (HAND HELD DATA
ENTRY DEVICE)

<u>RESPONSE</u>	<u>PROJECTED OEM PRICE IN 1985</u>
<u>PREFERRED</u>	
MILITARIZED KEYPAD	\$ 90
<u>DISPLAY</u>	
<u>PREFERRED</u>	
MILITARIZED SMALL FLAT PANEL (2 ROWS OF 40 CHARS; PRICE IS EXTREMELY SENSITIVE TO NUMBER OF DISPLAY CHARACTERS)	\$ 20
<u>PROCESSING AND STORAGE</u>	
<u>PREFERRED</u>	
8 BIT BATTERY POWERED CPU	\$ 100
16K NONVOLATILE RAM	\$ 50
2K ROM	\$ 10
PACKAGING AND POWER SUPPLY	\$ 50
	<hr/>
INTEGRATION (20%)	\$ 320
	\$ 64
	<hr/>
	\$ 384

CONCLUSIONS AND RECOMMENDATIONS FOR JOB TRAINING

- VISUAL DISPLAYS CAN USE STANDARD BROADCAST COLOR TV IF IT INCLUDES COMPUTER TEXT AND GRAPHICS. REFORMATTING IS REQUIRED FOR PRINTED TEXT, BUT YIELDS BENEFITS IN SPEED, EFFECTIVENESS, AND MOTIVATION.
- MEDIUM RESOLUTION COLOR GRAPHICS ADD OPTIONS FOR TWO DIMENSIONAL SIMULATIONS, GENERATIVE INTERACTIONS, AND REFORMATTING, BUT THE COST IS HIGH (ABOUT \$3,700). THIS CAPABILITY MAY BE RESERVED FOR SPECIAL APPLICATIONS AS AN ADD ON TO AN EXISTING SYSTEM.
- BEYOND 1985, HIGH RESOLUTION TELEVISION MAY BECOME A NEW STANDARD. THIS EVENT WOULD ALTER COST/BENEFIT RESULTS, AND SHOULD BE FOLLOWED CLOSELY.
- STILL FRAME AUDIO ON OPTICAL MEMORY STORAGE SYSTEMS (E.G., VIDEODISCS) IS ESSENTIAL FOR LOW COST TRANSFER OF TEC AND ETV MATERIALS.
- MANY ISSUES REMAIN ABOUT THE PLAYER.
THESE INCLUDE:
 - COST OF STILL FRAME AUDIO
 - PHOTOGRAPHIC AND MAGNETIC ALTERNATIVES
 - ANALOG VS. ALL DIGITAL STORAGE

- KEYPAD PLUS TOUCH PANEL IS ADEQUATE FOR INPUT, BUT AN INTEGRATED HAND HELD CURSOR CONTROL WITH KEYPAD SHOULD BE INVESTIGATED.
- TEC AND ETV CAN GO DIRECTLY TO NTSC VIDEO, BUT STILL FRAME AUDIO WILL REQUIRE REFORMATTING.
- PRINT REFORMATTING TO NTSC VIDEO REQUIRES CONSIDERABLE REFORMATTING.
- AUTHORIZING SYSTEMS AND TEXT/GRAPHIC EDITORS ARE ONE OF THE MOST CRITICAL FACTORS FOR EFFECTIVE USE OF THE NEW DELIVERY SYSTEMS.
- GENERAL ISSUES REMAINING INCLUDE:
 - A MANAGEMENT SYSTEM TO IMPLEMENT THE PLAN FOR CONTINUING INDIVIDUAL TRAINING IN UNITS, FOR MANAGEMENT OF TEAM TRAINING, AND FOR TRAINING RESOURCES.
 - TRAINING NCO'S TO TRAIN
 - INTERACTION STRATEGIES
 - INTEGRATING SQT'S AND SQT PRACTICE INTO JOB TRAINING
 - INTEGRATING ARTEP INTO ON-THE-JOB TRAINING
 - INTEGRATING JOB AIDING WITH TRAINING

CONCLUSIONS AND RECOMMENDATIONS
FOR MILITARIZED ELECTRONIC DELIVERY
SYSTEMS FOR SPA'S

- FLAT PANEL, MONOCHROMATIC MEDIUM RESOLUTION DISPLAY IS ADEQUATE. GRAY SCALE NOT REQUIRED.
- DEVELOPMENTS IN RUGGED SOLID STATE MEMORIES (INCLUDING OPTICAL POCKET-SIZED CARDS) SHOULD BE TRACKED CLOSELY FOR THIS SYSTEM TYPE.
- AUDIO OUTPUT DURING MAINTENANCE AIDING NEEDS TO BE INVESTIGATED IN THE FIELD, BUT DOES NOT APPEAR TO BE A REQUIREMENT.
- VOICE INPUT FOR MAINTENANCE AIDING NEEDS TO BE INVESTIGATED IN THE FIELD. CURRENTLY, INEXPENSIVE VOICE INPUT SYSTEMS ARE INADEQUATE. THE ADEQUATE SYSTEMS ARE VERY EXPENSIVE, BUT THEIR PRICE WILL FALL DRAMATICALLY WHEN THEY ARE PLACED ON A SINGLE COMPUTER BOARD AND PURCHASED IN LARGE VOLUMES.
- REFORMATTING FOR SPA'S WILL BE INVESTIGATED IN THE DATA BASE CORRELATION STUDY.
- AUTHORIZING SYSTEMS FOR SPA'S ARE NEEDED.

REMAINING ISSUES
FOR HAND HELD RATING AND INVENTORY DATA ENTRY SYSTEMS

- DESIGN OF THE DATA DISPLAY.
- FUNCTIONS TO BE PERFORMED (E.G., SCORING FOR SQT AND ARTEP, INVENTORY MANAGEMENT).
- STORAGE DEVICE.
- DESIGN OF THE KEYPAD.
- PROTOCOLS FOR EACH FUNCTION.

CHAPTER 1

INTRODUCTION: PURPOSE AND METHOD OF THIS STUDY

The Purpose of This Study

The mission of the Army Communicative Technology Office (ACTO) is to reduce the Army's reliance on the current paper and voice-based delivery systems. To do this, ACTO conducts research and development and develops specifications, all leading to the eventual introduction of new electronic information delivery systems. In fulfilling this mission, ACTO has initiated a series of research and development projects to analyze the costs, benefits, and engineering considerations related to electronic and optical technologies for information storage and communication. These studies have dealt with such topics as the costs of optical videodiscs vs. conventional print and audio-visual media, the effectiveness of videodiscs and microcomputers in training and in maintenance aiding problems, procedures for converting existing print and audio-visual media to new delivery system forms, and types of storage media technologies applicable to new distributed communicative electronic delivery systems. This is the final report in another study of this series. It deals with the presentation features of electronic delivery systems and their use in a variety of scenarios in the Army. In this chapter, the purpose and methods of the study will be reviewed.

The Problem

Before mid-century, the U.S. Army was much less complicated. There were far fewer weapon systems and these systems were of far less technological complexity. The work force available to the Army was more literate in the use of written and spoken English, and was in some ways better prepared in basic mathematical and technical subjects. The expense of conducting operations and training was much less. The equipment, its operation and maintenance was less complex and costly to deploy, use, and train. The major driving forces creating today's problems in training and maintaining are the following:

- (1) Technological changes
- (2) Societal changes
- (3) Economic changes

The technological changes include more, and more complex new weapon systems than ever before in the U.S. Army. While it is possible to use human engineered approaches and built-in test equipment to reduce the complexity of operations and

maintenance, these approaches often merely introduce new equipment or software complexity. It is not only the increase in complexity, but the increase in quantity of technological systems per soldier that increases the training requirements. There are more weapon systems and tools to operate and maintain, and they have become more complex and sophisticated in concept and operation. The net effect is increased requirements for training and for the selection of more technically qualified personnel.

To compound the problem of increasing demand for more technical skills, society has been changing. The labor pool is shrinking. As the number of 19 year-olds decreases, competition increases from business, industry, and the life of a welfare recipient. Thus there are fewer recruits available. In addition, the quality of the recruits has changed. An increasing number of them have Spanish or another language as their native language. Many have not been successful academically. This translates into lack of success with written and spoken English, the basis for the current delivery system.

Economic changes, occasioned both by the cost of the Army's inventory and personnel, and by economic inflation, have made it more and more difficult to provide realistic training. Ammunition and petroleum are too costly to be used up in extended training maneuvers. Transportation from one place to another where training can be obtained is increasingly costly.

The current delivery systems for recruiting, training, communications, maintenance, and logistics are primarily based on paper and on voice communications. This has resulted in an enormous increase in the volume of paper, a specific symptom of the underlying problems which prompted the creation of ACTO several years ago. Many publications cite the incredible growth in the number of pages required to document new weapon systems for both operations and maintenance. The processing of paper is a problem in all areas where human communication occurs for any of the Army's purposes.

In all Army activities, the limits of capability of the current delivery system are simply being exceeded. The paper management problem is one symptom. The inadequacy of training resulting in reduced force readiness is a more serious symptom. In many cases, today's soldiers are not able to operate or maintain the complex systems in our Army's inventory. Their non-English and non-academic background increasingly makes it difficult for them to obtain adequate training or to understand communications adequately through the current verbal delivery system.

The Opportunity

The opportunity to meet the Army's increasingly difficult problems comes from two relatively new developments in science and technology. One class of developments has produced new hardware and communication technologies, the other has yielded much broader and more complete understanding of teaching, learning, and communicating.

Hard Technologies

Modern technology has introduced many of the problems through invention of the many new and diverse weapon systems. It may also provide part of the solution. The opportunity arises from three powerful new technologies:

- (1) Computer chips which provide processing power for simulations, testing, records, scheduling, management aids, etc.
- (2) Optical memories which provide storage and distribution of video, audio, and interactive computer programs, and not just text.
- (3) Satellite and fiber optics communication networks which provide a new means for the distribution of information and for assurance that information is received and acted on properly.

It is through these new storage and communication technologies that ACTO can make a major impact on the current problems. The essential contribution of the computer chips is to permit the low-cost replication of interactions. Such interactions occur between skilled teachers and students, between a skilled coach and a person being guided in maintenance, between someone ordering and someone receiving in-office processing. The list is endless. The computer chips enable replication or prompting of many of the transactions that occur in interactive two-way communications between two or more people. Rules and doctrines for office work, personnel transactions, logistics transactions, training transactions, and maintenance aiding transactions can all be built in to the memories and programs that control the computer processors, on chips no larger than the little fingernail. These chips can be distributed, carrying the intelligence to reproduce or prompt these interactions reliably in multiple locations throughout the world.

The promise of optical memories is to move beyond the old delivery systems restricted solely to print and voice. Optical memories can store enormous quantities of video information, audio information, and interactive computer programs, as well as text. The pictures and text can be displayed in full color and with background audio on electronic display screens. Text can be greatly reduced and displayed in life-sized chunks, or can be associated with audio for poor readers. Large quantities of information can be replicated more inexpensively than can the same quantity of printed text and audio-visuals. Actual motion pictures modeling persons performing complex operational or maintenance procedures can be stored in optical memories, either as full motion with audio or as a series of still pictures with or without audio. Where print is inaccessible to semi-literate soldiers, pictures and audio are easily accessible and interactive programs provide the practice and prompting required to communicate.

It will be several years before satellite and fiber optics communication networks are fully implemented throughout the Army, but more primitive electronic communication networks now exist. Also, the ultimate goal of fully functioning networks can now be readily approximated by distributing data bases on computer chips and optical memories. That is, processing that now takes place centrally can be distributed out to the end users and only brief data summaries need be sent up the narrow-band communication channels now in existence. In the more distant future, broad-band communication networks can connect the distributed processes together. In either case, data accumulated in field operations can be summarized and commanders can be assured that training and operational missions are being carried out correctly in the field.

Soft Technologies

The other new development is a result of progress in soft technologies. Whether called science or art, these soft technologies have made great progress in the last 20 years. Many of the specialists prefer to call their specialty "sciences" (Instructional Science, Cognitive Science, Communication Science, Computer Science, Economics, etc.). Others are more pragmatic (Instructional Systems Development, Design Engineering, Message Design, Implementation Design, Configuration Management, Organizational Behavior). Whatever the preference for dividing disciplines up into specialties and naming them, practitioners experienced in the field are coming to recognize and agree upon a minimal set of processes, activities, and components in the total

picture of introducing new technological delivery systems into different social organizations and assuring their continuation.

In this paper, some concepts that have been developed by WICAT Incorporated in a comprehensive model of teaching and learning will be used to explain the minimum set of delivery systems for which communicative electronic systems should be developed. This analysis and presentation of a comprehensive view of these different delivery systems is presented in chapter 2. These new conceptions of both teaching and teaching support processes, and of learning and learning processes are a part of the new opportunity that presents itself. Failure to recognize all of the parts of the puzzle, parts which can only be solved by the soft technologies, is to fail to use the hard technologies properly.

As personnel in the Army begin to interact with electronic displays instead of printed pages, the question of presentation features of the displays and response devices provided becomes critical. The purpose of this study is to investigate these presentation and response features and to propose how they will affect the design of future communicative information delivery systems.

Method Used for This Study

The thrust of this project is to qualitatively analyze the cost/effectiveness for electronic delivery systems of a number of presentation features. The targeted features have been investigated in a number of studies in the human factors, educational psychology, and cognitive psychology fields. Therefore, one of the central elements of the study was to conduct a literature review, paying particular attention to the recent summarizing statements and guidelines of a number of investigators. These results are primarily presented in chapters 3 and 4, which are concerned with instructional design and human factors considerations for presentation features.

In order to gather data from the actual users, interviews were conducted with army personnel in many different programs. Visits were made to Ft. Sill, Oklahoma; Aberdeen, Maryland; Ft. Bliss and Ft. Hood, Texas; Ft. Eustis, Virginia; Ft. Monroe, Virginia; Ft. Monmouth, New Jersey; Ft. Benjamin Harrison; and Ft. Gordon, Georgia. In addition, the Master Automation Plan Office (MAPS) was visited in Washington.

Army publications and regulations governing different programs of interest were also obtained and reviewed.

In order to check our understanding and feeling for the data, we engaged Frank Dater, one of the leading researchers in this field, as a consultant for a brief time at WICAT.

Experiments were another important element in the study. Since the videodisc may be one of the central elements of an electronic delivery system, we decided to use several actual videodiscs for our studies. In order to do this, we first placed a series of dials and gauges taken at calibrated distances on the back of a videodisc made for the Defense Advanced Research Projects Agency (DARPA). These graduated and calibrated images permitted us to estimate the resolution of a standard NTSC videodisc and monitor. This information was also helpful in determining the extent to which reformatting may be required for existing printed materials in order to place them onto a low to medium resolution videodisc system. The results are reported in Experiment 3 (Appendix B).

We were also fortunate in that we had just prepared a videodisc for the Army Research Institute (ARI) which included training and simulation for a relatively complex artillery procedure. We were able to reprogram this procedure for the Presentation Features project in order to evaluate the effectiveness and preference by students for a number of different input devices. The results are presented in Experiment 5 (Appendix D).

As part of this study we had determined that the existing research showing no difference between line drawings and full color pictures had for the most part been conducted using only paper and pencil performance measures. We therefore decided to determine whether these results hold up where performance is measured by a hands-on task. A special disc was designed for this purpose. The disc included instruction and job aids which varied type of graphic (photograph versus line drawing), audio versus no audio, and lengthy description versus very brief action-oriented statements.

SONY agreed to master this disc without charge. Unfortunately, the mastering was greatly delayed and the disc that was returned to us had been truncated part way through the presentation of the materials. Therefore, Experiments 1 and 2 which required this disc were both delayed and changed in scope. The results are presented in Appendix A. In brief, we found no advantage for color photographs over line drawings for a hands-on test. We also found that accuracy using job aids was as good as with instruction, and that job aids saved time when both training and job performance times were considered. In all, we feel that some valuable data has been obtained from Experiments 1 and 2 and, indeed, from the combined experience with the three videodiscs.

Other experiments investigated transfer of print materials to an electronic delivery system.

One of the central questions which must be addressed when considering use of an electronic system is the extent to which present text materials must be reformatted in order to be easily legible on the monitor. It is also an issue as to the resolution required in order to place text pages onto a video monitor without reformatting. At some level of resolution, a page can be simply photographed using a camera and reproduced electronically. Experiment 4 was designed to find that resolution. The results are presented in Appendix C.

Another issue of importance is the expense to be anticipated when converting existing Training Extension Course (TEC) lessons from the current Beseler Cue/See format to video format. In order to gain this information, we actually transferred a TEC lesson and then reformatted other material in order to determine time and costs. The results of these investigations are reported in chapter 5.

Presentation Features Criteria

Candidate presentation features considered in this project were evaluated against three major criteria: effectiveness, cost, and other benefits.

The effectiveness criteria are based on user comprehension of presented information, the rate of comprehension, the amount of retention, and user acceptance and motivation. In most cases it was not possible to quantify the degree to which a delivery system produced changes in these areas. Nevertheless, it was often possible to compare alternate systems on these criteria for a given content matter and group of subjects.

The cost of a feature can be measured in many ways. Perhaps the most obvious is the hardware acquisition cost. However, this is usually outweighed by costs of hardware ownership, which are dramatically affected by the reliability, availability, and maintainability of the system. While these must be designed into the actual hardware and thus are not the province of this study, they are critical to system acceptance. Another major factor in the cost of each feature is the software and courseware development required. While there is no simple means of describing the relationship between a feature and the difficulty of developing materials for it, it is clear that different kinds of costs are involved. For example, preparing a computer-assisted instruction lesson using a standard monochrome CRT with no graphics capability can be quite simple since the capabilities of the delivery system are quite limited. On the other hand, preparing an interactive video sequence for a videodisc can be extraordinarily complex. It must be recognized that more capabilities may also mean more difficulties and expense in preparing materials. For example, should still frame audio ever become available on a videodisc, we would not be surprised to see someone try to utilize all of the hundreds of hours of audio time available. There is a kind of tyranny in great possibilities.

Another major cost is software update and revision. An optical videodisc of the type currently in use cannot be revised. This is a serious handicap for small volume programs which cannot afford to revise the disc to meet changing doctrines, hardware, and the like. On the other hand, the computer permits very rapid updates of information stored in its magnetic memory. By marrying the audio visual capabilities of the videodisc with

the rapid update capabilities of the microcomputer system, it may be possible to make less expensive updates and revisions to electronic delivery system programs.

The third major criterion is the type of benefits provided. One type of benefit is simplicity of use. Another is compatibility with existing delivery systems like print and Cue/See. Others are compatible components, and rapidly expandible, easily replicated systems which are available for fast response in case of mobilization.

Organization of the Chapters

The work in this project consisted of three major components. The first was to define how the systems will be used. Chapter 2 presents this information. The second component was to use the existing research and new experiments to determine the effectiveness and other benefits of candidate features. The results of this work are reported in chapters 3 through 7. The last component was to estimate costs for quantity purchases in 1985 to obtain the different features. A cost benefit tradeoff was used to recommend a set of preferred features and a set of lowest feasible cost features for each type of system. This analysis is presented in chapter 8. Chapter 9, "Looking Ahead," presents the most important points from all three components.

CHAPTER 2

SCENARIOS: REQUIREMENTS FOR ELECTRONIC DELIVERY SYSTEMS
TO IMPROVE COMMUNICATIONS, TRAINING AND MAINTAININGPRESENTATION FEATURES

In a previous report in this ACTO series*, six scenarios, each with several sub-scenarios, were defined. A scenario describes new but realistic ways that electronic delivery systems may be used by Army organizations. As scenarios are made more and more specific they lead to development plans. These influence several key activities: the design of the new electronic delivery systems, the reorganization of the work now being performed by each Army work group considered, and a strategy for moving from the current to the future scenario. This chapter will not repeat the description of the six scenarios given in the previous report. However it will attempt to make these scenarios more understandable in relationship to ACTO's mission. This chapter will, in addition, describe a few additions to scenarios from the previous report. Finally, this chapter will take a first cut at defining that minimal set of hardware components that can be used interchangeably across the various scenarios.

The discussion in this chapter flows from the general to the specific. First ACTO's mission is defined and the kinds of organizations are identified whose work could be improved by the use of electronic technology. Five different kinds of teaching systems are identified. The various sub-scenarios described in the previous report are related to these five kinds of systems. The scenarios describe how electronic technology can improve the productivity of the work performed by each kind of organization.

The chapter concludes by identifying a set of five different delivery systems that can be used across the scenarios.

It is important to narrow the requirements for electronic delivery systems in this way and find a minimal set that can be used interchangeably across scenarios. The problem is that as the electronics industry continues its enormous growth worldwide, a seemingly endless stream of new applications and products flows forth from this industry. These products, unfortunately, may be poorly matched to the Army's requirements. What is the minimum family of electronic delivery systems, some for training, some for maintenance, some for management, some for office work? A minimum but inclusive set of modular hardware and software components will give the Army (and perhaps other agencies of the Department of Defense) several advantages. One advantage is the economies of scale. Other advantages are simpler maintainability,

* Bunderson, Pett and Bearnson, Storage Media for Electronic Delivery Systems, ACTO Technical Report, Feb. 1981.

simpler training and education of Army personnel in the use of the new delivery systems, and other advantages. By contrast, a piecemeal approach to this problem will saddle the Army with a variety of incompatible and expensive electronic systems, many of them adapted wholesale from the consumer market and utilized in Army situations where they do not fully meet the requirements. In order to define a minimal set of scenarios some logical analysis of ACTO's mission is required.

ACTO's Mission and the Organizations it Serves

The mission of the Army Communicative Technology Office includes the following major responsibilities:

- (1) Life cycle development and management of military systems for production, distribution, and delivery of doctrinal, instructional, and technical materials.
- (2) Exploration of military applications of electronics technology for conveying information in communicative systems.
- (3) ACTO is to serve as the principal focal point below headquarters, the Department of Army for organization and support for these activities.

In short, ACTO is to help the Army choose from communication of information by paper, which is producing so much paper the Army is in danger of "drowning in it," to electronic communication.

The Simplest Case Description of the Communication Process

As defined in earlier ACTO publications, the communicative process is:

"a method of transferring ideas that insures understanding of meaning and intent."

Generally, the communication process has been conceptualized as occurring between a sender and a receiver. This makes communication a two-person problem. That is, by identifying all variables and activities that take place in 2-person communication we have solved the problem for any number of people. However, even early writers in the theory of communication (Cherry, 1966) have discussed communication as occurring in networks of more than two people. What is the simplest case problem for analyzing communication? When a physical scientist approaches a difficult new area, he tries to define the simplest case problem. That is, a problem that has inherent in it all of the properties of the general case. Then the solution to that simplest case problem is general. It may be less useful to construe communication logically as a two-person or two-element problem (sender and receiver). It may be more useful to construe it as a three-person problem. This concept is

depicted in Figure 2-1. The objective is now for the sender to send the message to the first receiver and for the receiver to capture it fully, sufficient to convey it on to a third person. This is generally the situation in any real communication. There may be times when a sender needs to communicate a message only to one party, but most often, especially in a military chain of command, the sender desires something to happen as a result of the message. This most often involves a third person or several third persons. Thus, in Figure 2-1 we have depicted the simplest communication processes occurring between a sender, a receiver, and a second receiver communicating with the first receiver. The dotted arrow going back from receiver to sender indicates a chance to query, to "ensure understanding of meaning and intent" (ACTO definition). However, the real test of whether "understanding of meaning and intent" was achieved is through testing the message received by the third person. If this message has been received properly, then we know we have solved our communication problem, because the same processes can occur from a second person through the third person to a fourth person and so on. Thus, the three person communication problem represents the simplest case that is complete. Thus, in a command communication, it is essential that the message of a commander go through one or more intermediaries and be received properly by those at the line level responsible for carrying it out.

Training is a special case of communication. In teaching and learning, the communication problem becomes a three person teaching/learning problem. For example, in a TRADOC school, the learner receiving the message must do so thoroughly, and must continue to work to perfect his mastery of the job taught so as ultimately to be able to communicate to co-workers (third persons) about it, use the skill in actual performances, and in some cases even teach it to someone else. In the case of training, the idea of a third person is a way of assuring that what is communicated in training situations is fully mastered and used correctly on-the-job, perhaps long after the initial training. This means that the learner is progressing up an Army career path, becoming an NCO or perhaps an officer who must teach others.

Figure 2-2 is another way to show the importance of what happens after the second person receives the message in an AIT school. The ordinate of Figure 2-2 indicates the percent of mastery in a military career (from 0 to 100%). The base-line indicates time--the soldier's life and career. Three time phases are indicated. The readiness phase involves the soldier's home and school experiences prior to joining the Army. Phase II involves face to face learning that occurs in a TRADOC school. Phase III is a much longer mastery of his military occupation. Figure 2-2 makes several points clear:

- (1) The readiness of the soldier has a great impact on what can be accomplished during the schooling phase in the modern Army. The soldier's grasp of written and spoken

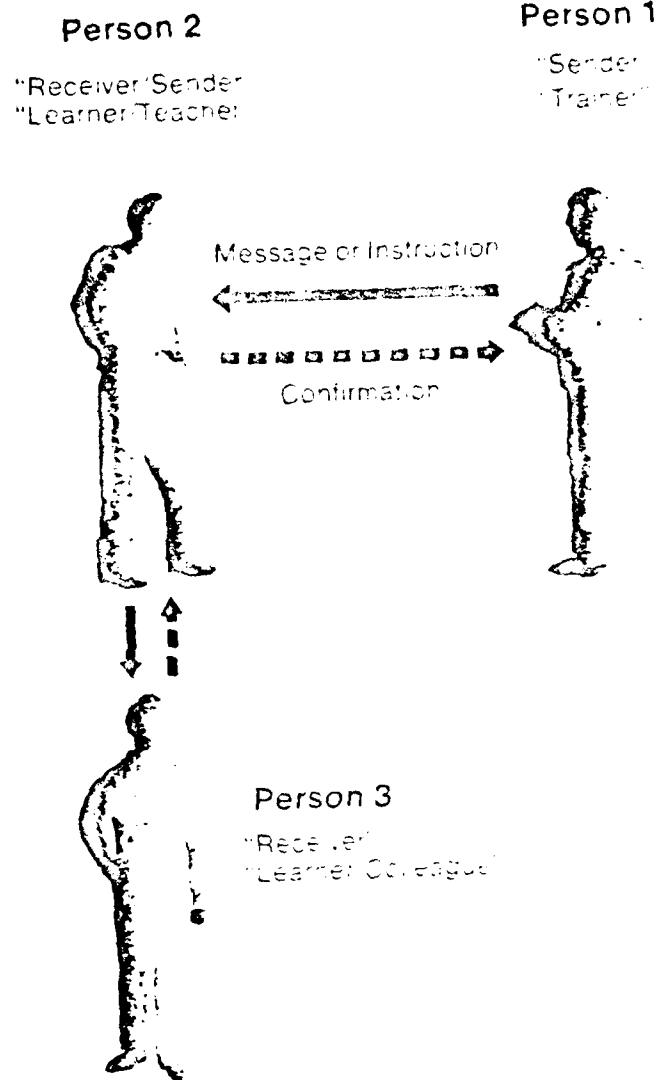


Figure 2-1 Communication or training is a Three-Person Problem

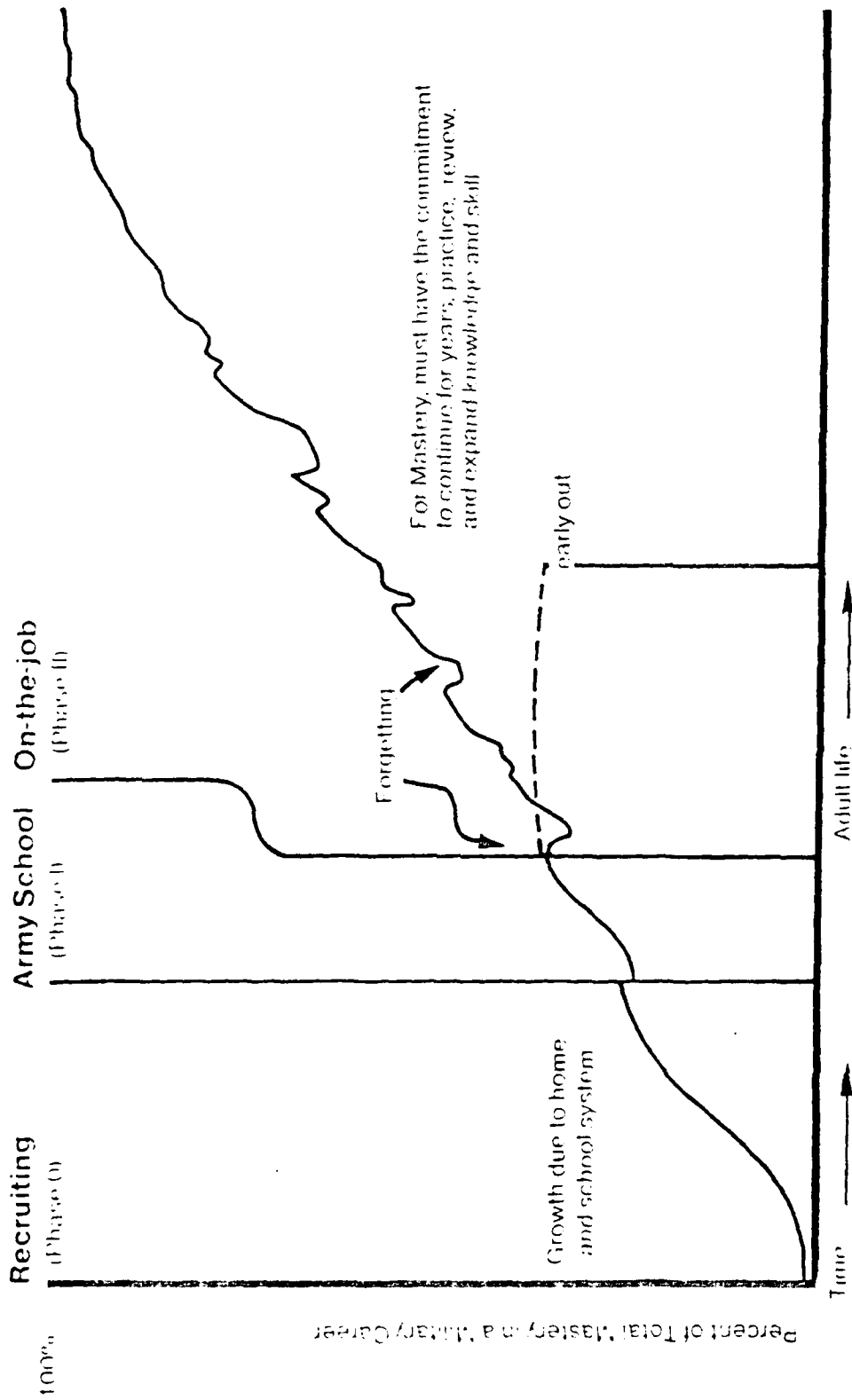


Figure 2-2 Three phase in achieving mastery in a military career.

English and of technical and scientific concepts is most significant in determining how well and how fast training information will be grasped. In addition, the soldier's personal habits, study habits, aspirations, and self concept are of great importance in learning initially and in continuing to grow.

- (2) The impact of the TRADOC school is small in the total time picture, but could be quite large in its effect. The experience in the TRADOC school affects the slope of the line during the on-the-job phase. This line could progress upward toward mastery, or could lead to so little on-the-job accomplishment as to contribute to an early exit from the service.
- (3) By far the most significant phase is the on-the-job learning phase. This is significant both on the basis of common sense and on the basis of necessity. Our common experience assures us that great learning occurs when we actually do the jobs that are mostly talked about during formal face to face schooling. Necessity has lead TRADOC to the doctrine that most training responsibilities must be exported to the units and must occur on the job.

Figure 2-2 makes the point that communicating mastery in a military career from a series of teachers to a learner is a long-term process and that ACTO's mission to "transfer ideas in a way that ensures meaning and intent" is something that must focus on the total career management of the soldier. This involves recruiting soldiers with a maximum degree of readiness, teaching during the formal schooling phase, and (most importantly) the teaching and growth that occurs on the job.

Looking at communication and training as a 3-person problem rather than as a 2-person problem is more consistent with the realities depicted in Figure 2-2. If, for example, we look at training and training support as occurring only between the school instructor and the soldier, we do not address the problem of carrying the training information and skills on to the persons at the soldier's later duty assignments. What will help the soldier realize that this is part of his duty? He may be called upon later to explain, to demonstrate, or if promoted, to teach others what he is learning. What materials and aids can be provided to help the soldier do these things later on the job? How can career counseling and assignments take place to keep the second and third persons at it long enough to achieve mastery--which will not have been attained during the TRADOC school phase?

Military Organizations and Their Delivery Systems

ACTO's mission is to help military organizations communicate and process information electronically instead of by means of current paper-based delivery systems. The goal of all of this is improved force readiness. A military organization is a group of people in defined roles who have a particular mission. Any organization has a set of regulations and unwritten traditions and uses a delivery system (set of technological tools) to accomplish its mission.

A delivery system may be defined as follows:

A delivery system is the technological component of an organization, used by the organization to aid in the accomplishment of its work.

This definition is much broader than the usual definition of a delivery system.

Current View of Delivery Systems. The current view of delivery systems is quite limited. Print and voice communications dominate and constrain our ability to imagine new ways of accomplishing the same work. In education and training, delivery systems are seen primarily as printed or audio-visual presentation devices which may or may not accept student responses. These devices are mostly passive, linear, and noninteractive and do not exploit the three powerful technologies discussed as opportunities in the last chapter. Thus, an expanded view of delivery systems is necessary.

Delivery Systems are More than Audio-Visual Presentation Devices. Delivery systems for communication or training need not be limited to presenting displays and accepting responses: delivery systems can effectively deal with all of the work involved in the various transactions that occur between three people in organizations- the three-person communication or training problem. These transactions can occur either face to face or in distributed remote configurations. The question then becomes, "How can the new technologies leverage all of the informative work in organizations?"

Successful Information Delivery Involves More Than Hardware.

In the first chapter the opportunity for the Army was seen as coming from both hard science and technology and soft science and technology. The soft science is clearly needed because delivery system hardware is not enough. The goal is to increase the productivity of the organizations as now constituted in their performance of the Army's missions. But as mentioned earlier, these organizations involve three components:

1. People in defined roles
2. Written and unwritten regulations and traditions
3. The technological tools or delivery system

ACTO can help Army organizations perform their work more productively through new technological tools--"hard technologies". The people and their traditions must be considered or the new tools will not be accepted or used properly. The three-fold definition of an organization is illustrated in Figure 2-3. The symbol for an organization using a delivery system used in the figures in this chapter is a large arrow emerging from a large bracket. Inside the bracket can be listed both the processes used in the communication, and the content to be communicated or delivered. The processes and content may be conveyed by some technological aids, or by the people in the situation. All of them operate according to a certain set of rules laid down by the governing body that establishes the right of the group to deliver its products or services. These rules are part of the traditions. A work climate, usually unwritten, is also a part of the traditions. The productivity of the organization can be improved by improving the abilities and skills of the people, by removing traditions that are counterproductive, or by improving the work climate. Mainly, the productivity can be increased by changing the technological tools. This is the area where ACTO is most closely identified. However, ACTO's mission to improve communication in order to "ensure understanding of meaning and intent" involves a full consideration of the persons and traditions which so heavily influence communication, teaching, and learning. Ensuring understanding involves soft sciences and technologies as well as the design of delivery systems.

In the lower half of Figure 2-3 is indicated an example of an organization that could use a new delivery system--face to face training in a TRADOC school. The people in this organization are the teachers and students. The technologies of the conventional delivery system are hard copy (books and fixed media).

The traditions include TRADOC training doctrine and the climate and morale at the school. The processes of work the instructor must perform include giving presentations, providing practice in work models (a model, simulation, or approximation to the work the soldier will later do on the job), providing motivational activities to assure that the soldier will remember what is learned and will continue to learn and improve after this day's lesson, and conducting management activities which ensure the good use of time and resources. The content of instruction which the soldier learns includes combat techniques and procedures (e.g. how to operate various pieces of equipment). Or it may be a support MOS in which the soldier learns to maintain equipment, supply material, or conduct administrative activities.

Organizations for which scenarios are needed

Careful consideration of the three-person problem led to the definition of five classes of organizations (or organized functions) needed to support both Phase I and Phase II training. Similar kinds of organizations are needed to support command through the entire three-person process.

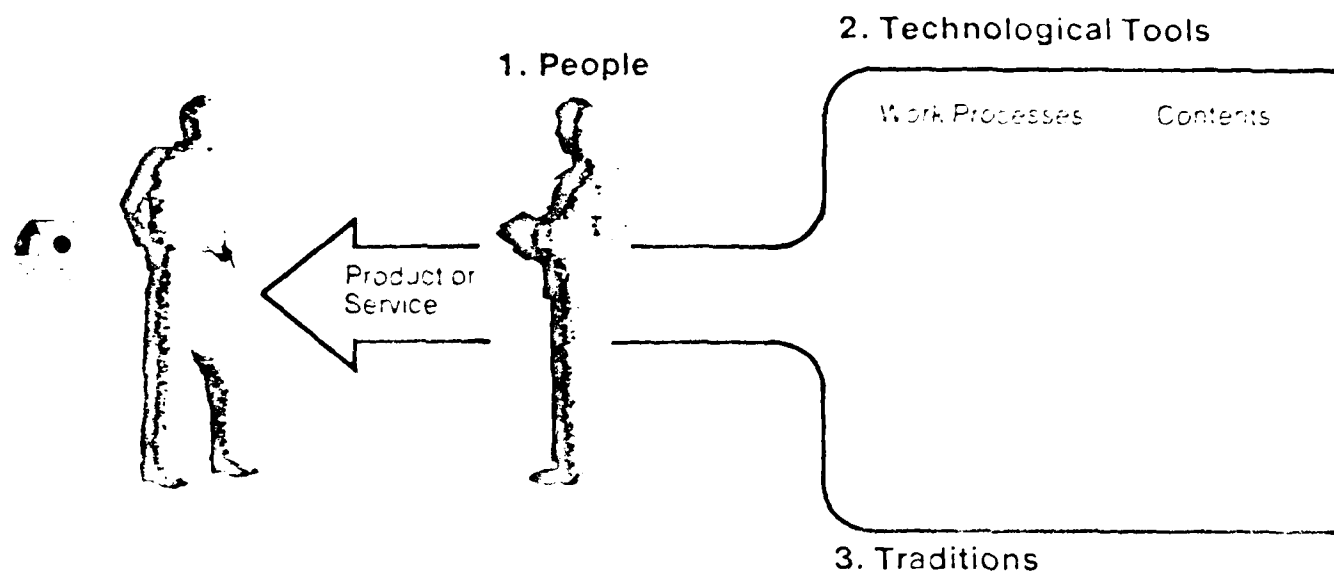


Figure 2-3a Components of all Delivery Systems

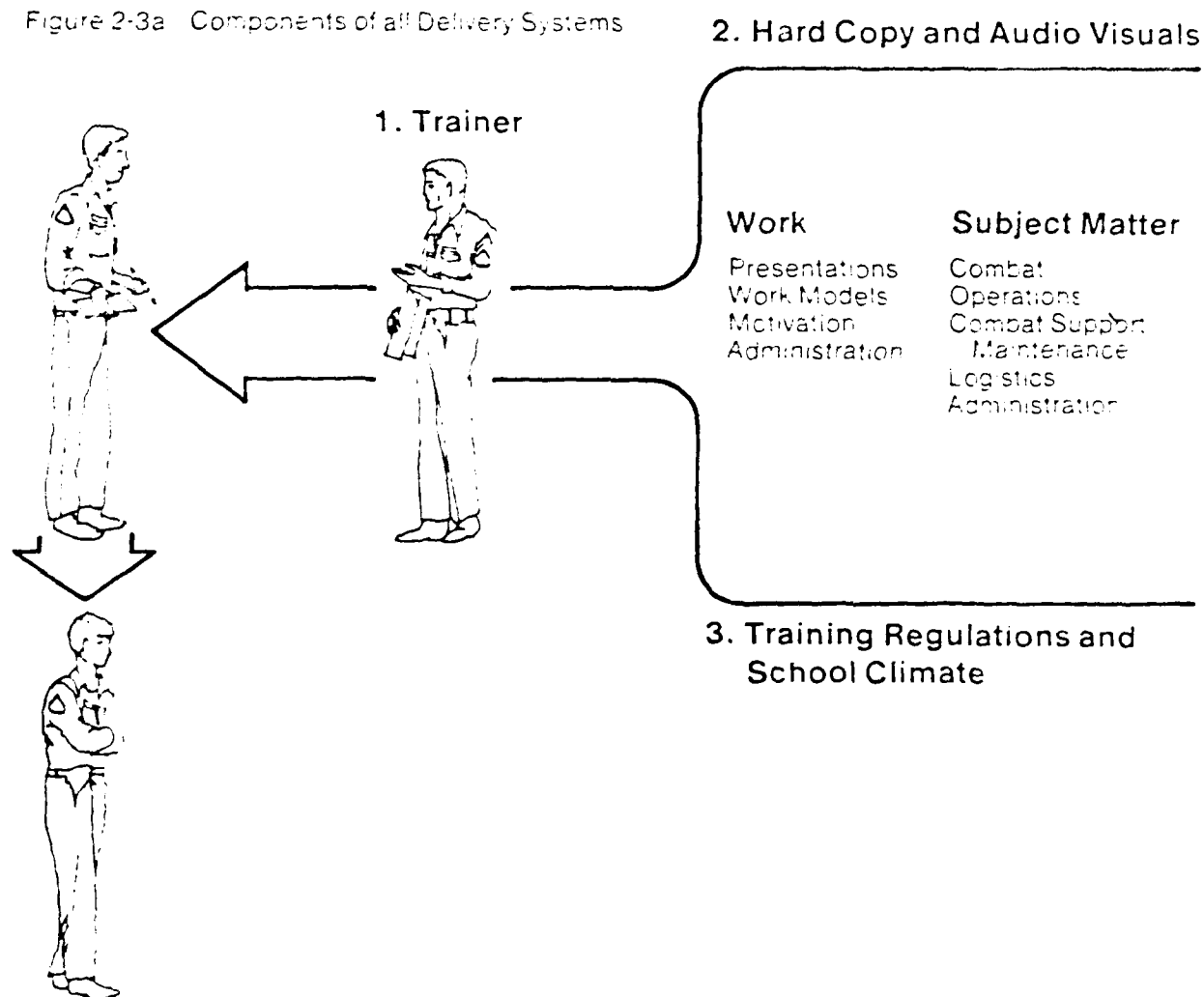


Figure 2-3b An example Face-to-face (Phase I) teaching

Figure 2-3 Three parts of a delivery system and the TRADOC school example

The reason for considering these organizations in this detail is that organizations reflect the delivery systems they use. The old delivery system, consisting of print and oral communication primarily, supports certain kinds of activities while other kinds of activities cannot be done conveniently or cost effectively at all. If these organizations do not carry out vital activities in a complete or satisfactory way, something new is needed. The three-person problem gives us a way of examining what would be required to solve these deficiencies of communicating or teaching all the way to the third person. It thus helps us to understand what new scenarios are needed. This in turn leads to new requirements for the family of delivery systems ACTO must design.

The five types of support systems needed to support all training activities necessary in the three-person problem are the following:

1. Phase I formal teaching delivery
2. Learner quality assurance
3. Teacher quality assurance
4. Materials development and improvement (ISD)
5. Phase II training or Future Assurance

These will each be discussed in turn.

1. Phase I Training at the TRADOC School. This type of teaching support system was introduced in Figure 2-3. The terminology Phase I and Phase II refers back to Figure 2-2 where Phase 0 (soldier's home and school experience), Phase I (the TRADOC schools), and Phase II (the on-the-job phase of learning) were compared and contrasted.

In addition to the TRADOC School, three other kinds of support systems, each with their own delivery systems, are needed just to support the school organization. These are presented in Figure 2-4. The standard symbol for a system with a mission is used for each of these three new organizations; that is, a bracket terminating in an arrow pointing in the direction in which the goods or services are being rendered. These three new support systems are numbered 2, 3, and 4. The diagram is designed to be self-explanatory.

2. Organizations That Deal with Learner Quality Assurance. The U.S. Army Recruiting and Enlistment Command (USAREC) and the Military Enlistment Processing Command (MEPCOM) have major responsibilities in the learner quality assurance process, one of the support systems logically required by this analysis. These commands are concerned both with "learner quality" (physical and mental fitness), and also quantity. Readiness requires that units be fully staffed. Learner quality assurance deals with Phase 0 in the diagram in Figure 2-2. That is, selecting from the population those recruits who can be attracted away from other opportunities they might have, and who score as high as possible on physical, language, and technical skills related to their eventual jobs.

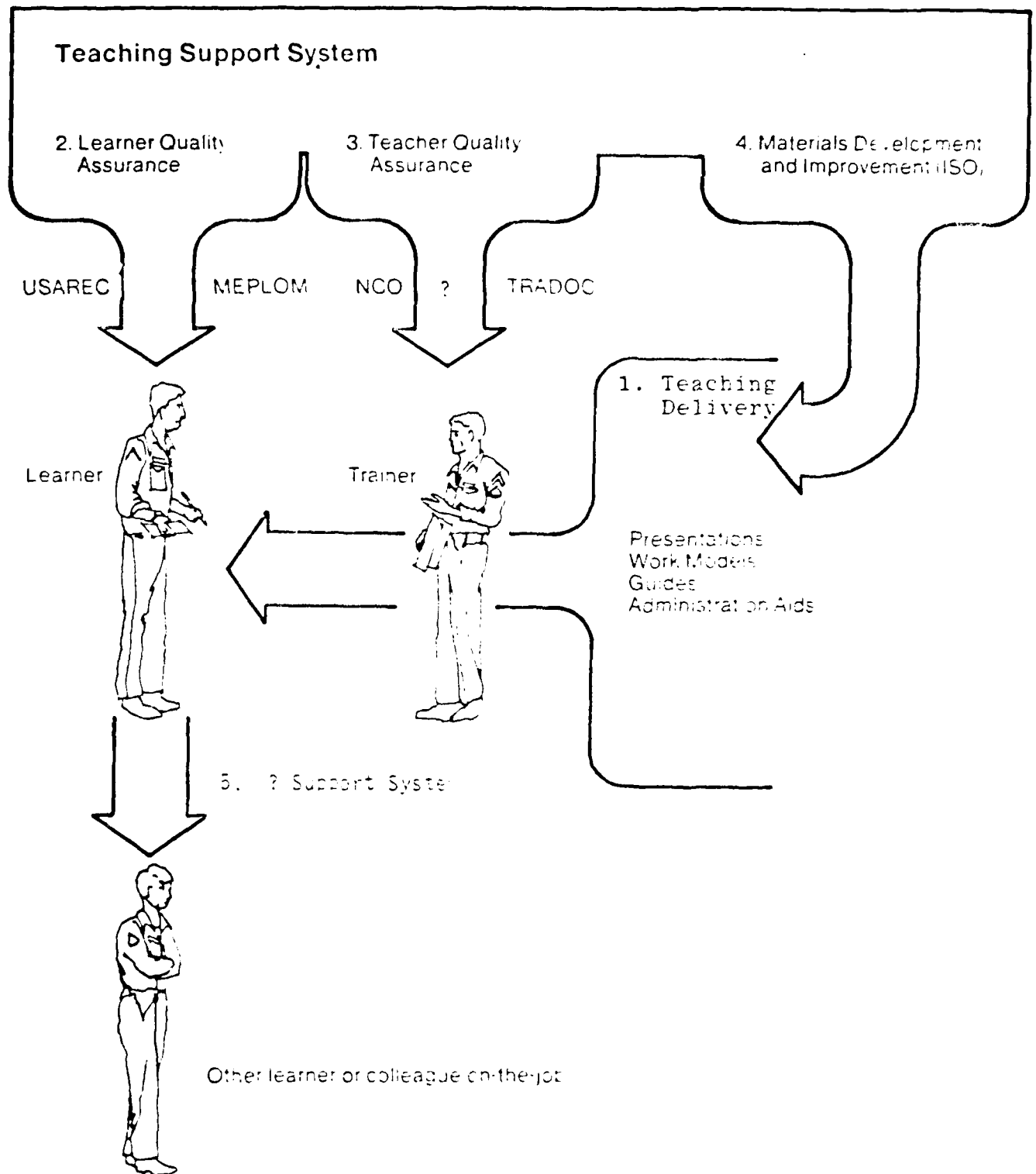


Figure 2-4 Four main delivery systems for solving the Three-person teaching problem (Phase I, TRADOC Schools). A fifth system is needed for reaching the third person(s) on the job.

The mission of assuring learner quality is broader than USAREC and MEPCOM now conceive their role. Learner quality assurance can also involve improving the learning skills and strategies and the basic skills (language and general technical knowledge and skills) of the soldiers. The BSEP program (Basic Skills Education Program) is one program which deals with this other aspect of learner quality assurance.

3. Teaching Quality Assurance. There are two kinds of mastery that must be attained by NCO's and officers in the Army. One kind of mastery deals with their military occupation specialties; and, as they advance, with broader issues of leadership and command. The second kind of mastery deals with teaching mastery. This has many components, but includes the understanding of Army training doctrine, the ability to administer presentations and work models (practice situations that model as closely as possible the soldier's ultimate work), the ability to motivate soldiers to learn during the course itself and afterwards, and the ability to manage skillfully time and resources associated with teaching activities. TRADOC has many programs to assure quality of instructors at the schools. Questions arise, however, in considering the three person problem when the trainer is an NCO out on the job instead of an instructor at a school. In addition to teacher quality assurance for the NCO, the three person perspective reminds us to consider the sharing of information from one soldier to another on the job. The lack of good teacher quality assurance for the second person (NCO) and third person (soldier who must communicate with others) is a serious deficiency in the system. These deficiencies are indicated by the question marks in Figure 2-4. The number "5" by the small delivery system symbol going from the learner to other learners on the job suggests the need for another delivery system not indicated in Figure 2-4. This issue will be dealt with later.

4. Materials Development and Improvement (or ISD). This system is implemented at several sites. The TRADOC schools have the primary responsibility for developing job training materials in the areas of their proponentcy. The U.S. Army Training Support Center (ATSC) at Ft. Eustis has the responsibility for managing the various exported training programs such as the TEC program, the SQI program, the job training program, the Army correspondence course program, the Army training literature program and others. The Tobyhanna Army Depot is responsible for duplicating and distributing the exported training materials to the field and a variety of materials to the schools. As the symbol going from materials development to delivery system #1 shows, these materials must include presentations which can be utilized by the trainers, work models to provide practice, guides to prompt motivational activities, and administrative aids. These four items listed in system #1 are shown as being provided, at least in part, by system #4. These four items help clarify why distributed training is so hard in execution. When the soldiers are out on the job, their instructor is an NCO or training officer. He has not in general had instructor training activities like the

instructors at the TRADOC schools, and he does not have the facilities. He does not have the extensive TASO support for audio-visual materials. He may not have conveniently located learning centers or audio-visual devices or libraries of printed and audio-visual materials readily available to him and the soldiers in his command. The point here is that training and training support are well developed and implemented at TRADOC schools, but that the TRADOC philosophy of exporting the majority of training to the field must recognize the need to provide the same kinds of support in distributed training. That is, all of those variables and activities--all the work needed to make training effective in a school environment must be transformed and exported, along with presentations, in order to make training effective in the on-the-job environment. This has not fully been possible because of the limits of the old delivery system. The old delivery system cannot replicate interactions, nor much video and audio to make instruction motivating and powerful. However, the opportunity now exists to implement a delivery system with new technological tools fully capable of supporting training on the job. This is discussed in the next section.

5. Phase II Training or Future Assurance. Figure 2-5 illustrates the needed fifth system for supporting the all-important on-the-job training processes. The dotted lines in the figure shows how the TRADOC school phase (Phase I) is now a thing of the past for the soldiers and NCO's involved. The soldier has left the school and is now in a unit. After a time, some of them have been promoted to be NCO's or training officers themselves and are now required to teach the "third person." Those who are not formally responsible for training still need to teach or communicate (or at least to demonstrate) what they have learned to other soldiers or co-workers in their unit. If we can support these several persons as teachers or communicators, we will have solved the three person problem, and will have assured that, in training, the ACTO definition of communication as "a method of transferring ideas that ensures understanding of meaning and intent" is indeed achieved. The problem of inadequate teacher quality assurance discussed in the last section is solved by expanding the materials development function to include built-in training materials for the NCO or trainer in how to use the packages that are being sent out. There is no reason to expect that NCO's or trainers on the job will know how to train, even given excellent materials like the TEC lessons that have been distributed in the past. These have been used by a disappointing portion of the NCO's. The future assurance process should also consider transactions between the second and third person after initial training activities. After initial training activities are conducted by the NCO's and soldiers in unit learning centers at the battalion or company level, these people must go out into job sites in repair bays, offices, or the field and perform the work they have learned. As an extension of the future assurance process, job aids and guides should be available to them for their own work, and also usable by them in teaching one another (or at least modeling correct job performance to one another).

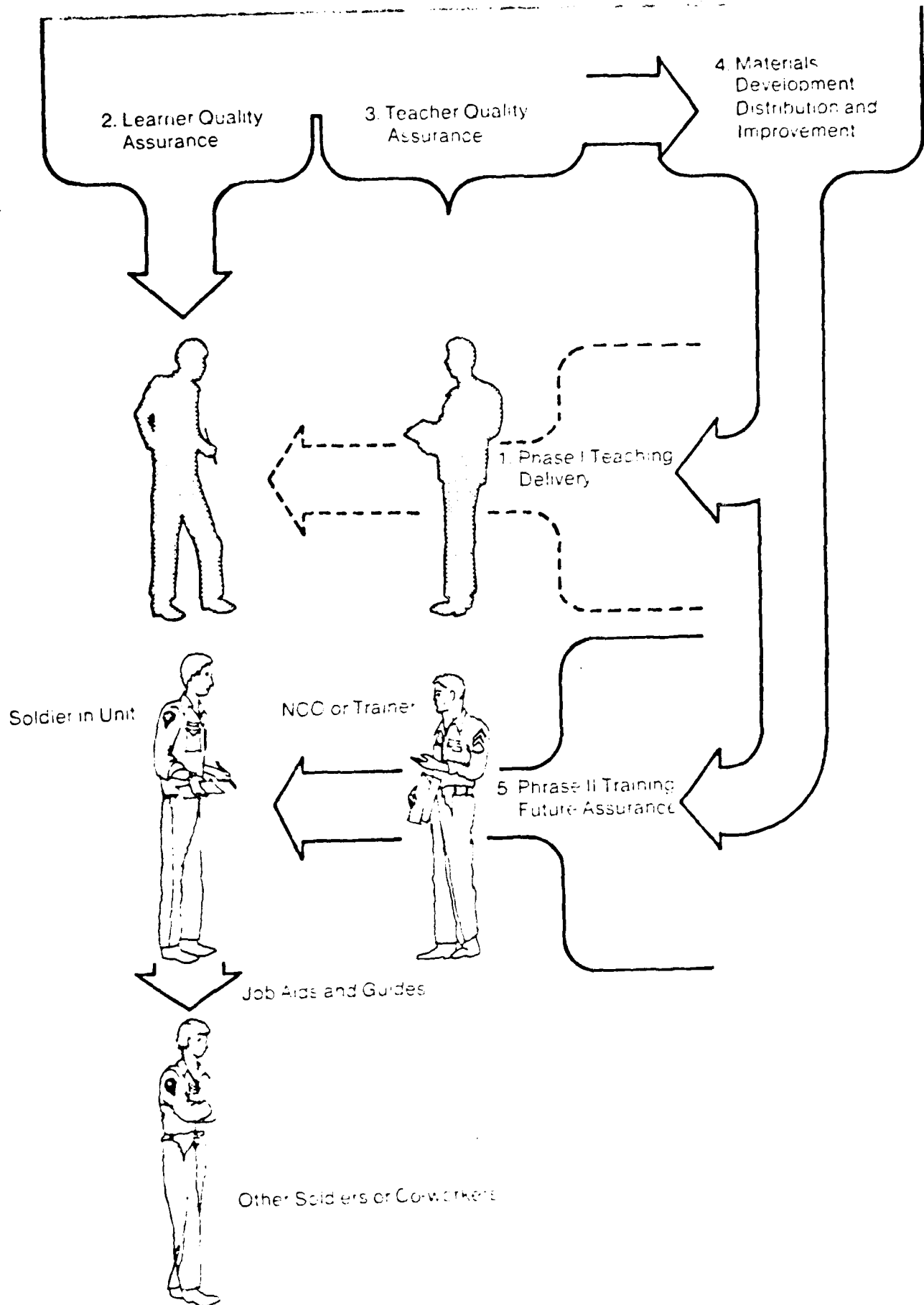


Figure 2-5 The fifth main delivery system for Phase II on-the-job training. The Future Assurance system and its relationship to delivery system #4

Previous efforts at distributed training have been severely criticized because of these deficiencies in being useful and used on the job. Insufficient success has been achieved in training the NCO's to use the distributed materials correctly, and in assuring that "the water gets down to the end of the row". Put another way, the Army has not solved its three person problems in assuring that training on the job is correctly executed and gets the desired results.

The feedback paths for assurance data are not shown on the diagrams in Figures 2-4 and 2-5. The feedback data paths could be indicated on the charts as electronic signal paths going back from the second and third persons to the sending agency. For materials improvement, the sending agency is the TRADOC school, or ATSC, which requires data on the effectiveness of the materials distributed.

Figures 2-4 and 2-5 can be adapted for communications other than training, and signal paths can be depicted going back to the agency involved. For example, in the SPA's program, it is important to know whether the job aids are functioning properly on the job in increasing the number of ready weapons systems and decreasing down time and cost of false or erroneous repairs. An important consideration in ACTO's design of new information systems to support these delivery systems must be upstream feedback paths utilizing network communications technologies.

The Need for Feedback Data to Assure That Messages and Training "Reach the Third Person." The reader might be tempted to assume that the symbol chosen for the work of an organization, an arrow emerging from a bracket, implies one-way communication. This is definitely not the intent. The implication is two-way communication. The use of the word "assurance" in three of the delivery systems and "improvement" in another one implies considerable interest in data to assure that the mission of each organization is being accomplished. To solve the three-person problem, this assurance data must be obtained from the final end users, symbolized by the second and third person or persons.

THE SIX SCENARIOS AND THEIR RELATIONSHIP TO THE FIVE TYPES OF SUPPORT SYSTEMS

In a previous ACTO study, "Storage Media for Electronic Information Delivery Systems" (Bunderson, Pett, and Bearnson, 1981), six scenarios with several sub-scenarios were described in detail. These scenarios can now be grouped under the five logically necessary delivery systems derived in the last section. This grouping is as follows:

1. Scenarios Needed for Phase I Teaching Delivery (TRADOC School

Scenario 3a, Teaching Delivery at a TRADOC School (or any other formal training facility).

Scenario 2b. Where maintenance MOS's are taught at a formal school, the same SPA's delivery system for field use could be used during training. Soldiers would be familiar with the maintenance aiding equipment when they went out on the job. This is a good solution to the three person problem. A person already familiar with his eventual tool would be able to utilize it during Phase II of his career. He would be able to demonstrate the correct use of it to others as they came on the job.

Scenario 3b. Two-dimensional simulation in the TRADOC schools.

2. Scenarios Needed for Learner Quality Assurance

Scenario 4. Electronic Delivery System for the recruiter.

Scenario 5. Electronic Delivery System Support for Administration and On-Line Testing at the Armed Forces Enlistment and Evaluation Centers.

Scenario 1b. On-the-job learning using an electronic delivery system to improve basic skills (e.g., BSEP program).

3. Scenarios Needed for Teacher Quality Assurance

This function has no single "home" and is not fully and effectively implemented at this time. In terms of electronic information delivery systems, it would use the same delivery systems used in Scenario 3a at the TRADOC school during formal teacher training activities. On the job, it would use distributed information delivery systems for NCO training. The materials development delivery system must have a significant role in developing trainer training materials and seeing that they are packaged along with the job training materials for soldiers. Otherwise, this vital function will continue to be performed poorly or not at all, as at present. This analysis may indicate the need for organization of some proponent for teacher quality assurance on the job.

4. Scenarios Needed for Materials Development, Distribution and Improvement

Scenario 3a. Materials Development at the TRADOC Schools. Also, general support from ATSC at Ft. Eustis and Tobyhannah, and by other Army organizations for developing materials or managing contractors.

5. Scenarios Needed for Phase II Training or Future Assurance

This function requires the most new development because it is the one that has been least adequately implemented. Thus, it has the most new scenarios associated with it. Included are:

1a. The use of distributed electronic delivery systems by the NCO.

- 1b. The use of distributed electronic delivery systems by the individual soldiers.
- 1c. The use of electronic delivery systems and portable memories for management of training.
- 1d. The use of distributed delivery systems and portable memories for group training and the ARTEP.
- 2a. The SPA's delivery system for maintenance aiding on the job.
- 2b. The SPA's delivery system for maintenance job-training on the job using ETM.
- 2c. The use of electronic delivery systems and portable memories for logistics control on the job.

With but a few exceptions, the detailed discussion of these scenarios is found in chapter 8 of the Storage Media Report (Bunderson, Pett, and Bearnson, 1981, pp. 113 through 181). This chapter has not been revised for this study. The chapter is quite extensive and cannot be repeated here. The exceptions and changes to the published discussions are as follows:

- (1) Scenario 1d has been modified by follow-up investigation of portable memory technology. The storage media project showed that the magnetic stripe technology was not adequate as a portable memory for the soldier's training and training management records. However, three new technologies are excellent candidates. One is a chip in a card, the other is a chip in a rugged object like a plastic key, and a third is an optical direct read after write strip on an I.D. card. These portable memories are illustrated in the scenarios shown in Chapter 8 of the previous report. However, scenario 1d was not sufficiently explicit in how the NCO would obtain ratings on soldier's hands-on component and job-site component performances or how the NCO would obtain quantitative scores (at least "go" and "no go") for ARTEP tasks. The solution to this problem is to provide a hand-held prompting and scoring device that the NCO, trainer, or tester can take into any location to observe manual performances by individual soldiers and by groups. The hand-held device would prompt one by one on the different tasks that were to be performed and the rater would enter "go/no-go" or numerical ratings into the hand-held device. This device might have in it a very small reader/writer for the portable memories associated with the individual soldiers or with the individual units and these memories could be updated instantly. Alternatively, the hand-held prompting rating device could be simpler. It could keep the records in an internal memory which could

later be read into a work station. When the portable memory (e.g., I.D. card with memory) belonging to the individual soldier or the unit leader was later read into the work station, it could be updated.

- (2) Scenarios 1b and 1c, which describe how the soldier uses job-training discs to obtain individual training, needs to be updated in a minor way as a result of the analysis of the Learner Quality Assurance delivery system. In addition to job training discs and interactive programs, BSEP materials could be implemented for delivery on-the-job. This requires no changes in the procedures for scenario 1b, but requires that BSEP be integrated into the Plan for Continuing Individual Training in Units (PCITU) discussed in scenario 1c.
- (3) Another scenario that needs elaboration is that of the electronic office. The important elaboration is to consider the requirements of command and control for force commanders. The important consideration is whether special provisions must be made for the administrative and control activities associated with command and control hardware and software in the commander's office, whether in a garrison or in the field.

The Role of the Memory Card in All Scenarios

The concept of a portable memory card (or small object containing a memory) has considerable significance to all of the scenarios. There are two reasons for the importance of this concept:

1. The portable memory and I.D. card can serve as the "key" to unlock the system and in so doing, can provide assurance data on utilization and performance. This data can be summarized and utilized by higher commands.
2. The portable memory makes possible the distributed network in which all of the work stations in an area can be stand alone. No "wiring up" is required since data can be transferred from work station to work station manually on the cards.

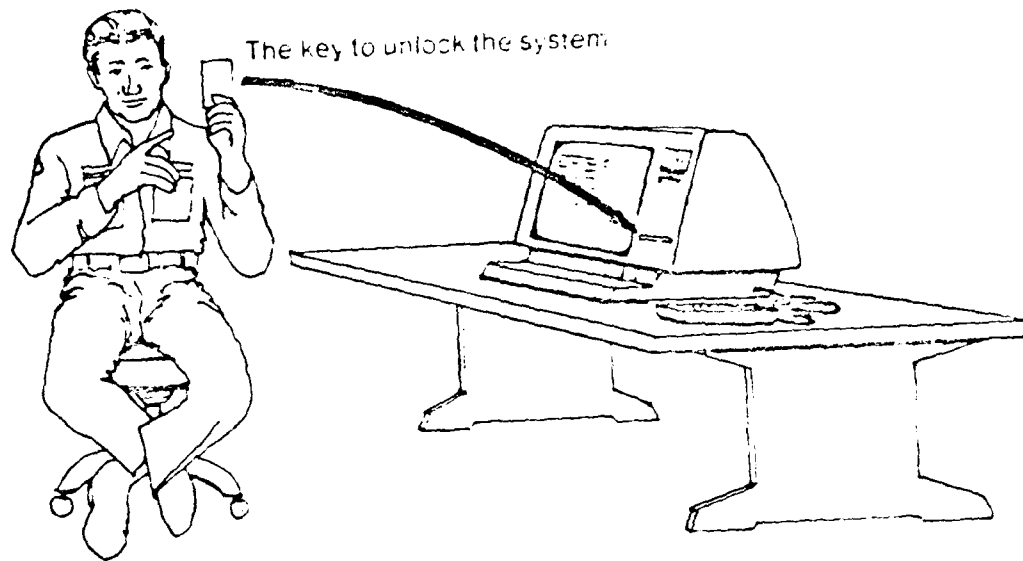
1. The card as "key" to the system. Using a small portable memory as a way of obtaining access to any station has several advantages. First, it reduces input errors. Entering the social security number or some other code number or name can be time consuming and error prone. The card contains all identifying information for any user. A short password or passcode can be associated with it for security if necessary, but in either case, access to the system is greatly simplified.

Second, since the card contains an updated version of the soldier's training information and history, this and the current transactions can be logged in the non-volatile memory of each work station. This is an unobtrusive way to collect data on utilization of a system. Whether or not the utilization is achieving good results can be determined. This for the first time makes training accountability a possibility. Third, frequent insertions of the I.D. card into each work station allows back up copies of the soldier's record to be made from time to time. This provides security in the event of loss or destruction of the card.

Figure 2-6 illustrates the I.D. and portable memory card as the "key" to unlock the system. Figure 2-7 illustrates three promising technologies that should be explored for use as the portable memory. The I.D. card with chip in it is illustrated at the right side of Figure 2-7. The chip is stored under the small circular contact plate in the upper right hand corner of the card. Tape bonding techniques are now available to package integrated circuit chips in standard-sized credit card plastic stock. The object in the center is a commercially available "data key." The key is inserted into an inexpensive receptacle and turned to engage the portable memory. The key is quite rugged and could be included on the dog tag chain or a key ring in the soldier's pocket.

The third competing technology is depicted at the far left of the figure. The Army has already decided to use the magnetic stripe technology on an I.D. card. This is inadequate for the purposes discussed herein. However, a new technology, the optical strip, developed by Drexler Industries, is a candidate technology. This strip could be distributed on the same card as the magnetic stripe but would use a different reader with a laser. The laser would burn microscopic pits in the optical strip as new information had to be accumulated. This is a non-erasable medium and would not be subject to damage by magnetic fields. The record is permanent. There is so much storage space available (about 3.6 million bytes) that the card could be used for a long time before it would have to be replaced with a new card (or a new strip on the same card).

2. Portable memories reduce network requirements. Since each soldier carries his own training record on a portable memory, there is a way around "hard wired" local networks. These may not be feasible in some military locations. Stand-alone work stations will do the job so long as they are each equipped with their own secondary storage, such as floppy disks, bubble memory, or Winchester disks. Figure 2-8 depicts an NCO who has gathered the cards from his own squad, or in the case of a company commander, from his platoon leaders. He is about to read them into an administrative station so



ID and Portable Memory/ card

Figure 2-6 The I.D. Card Portable Memory
as the Key to Unlock the
System.

Three Candidate Portable Memory Technologies

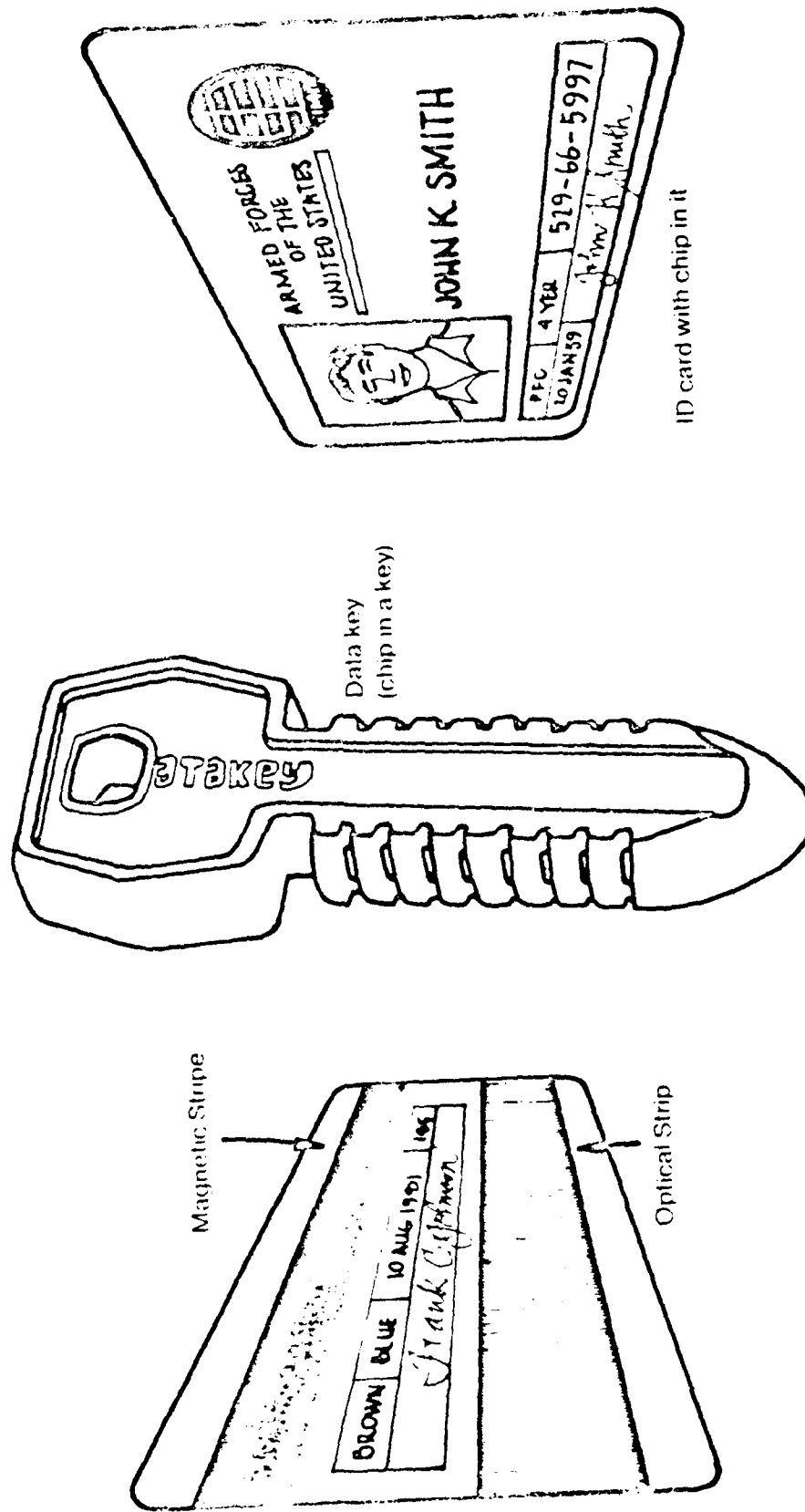
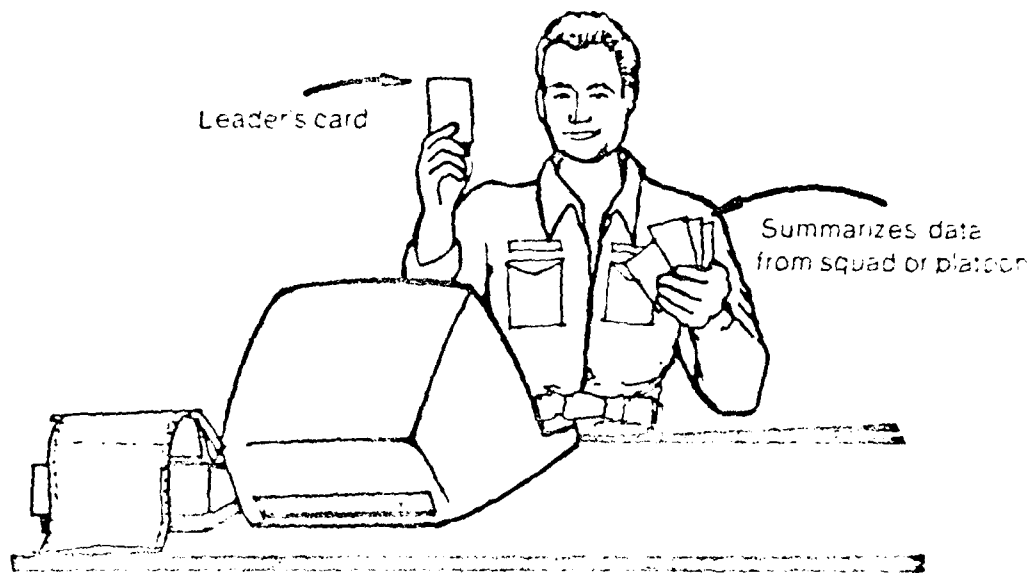


Figure 2-7 Three Promising Technologies for Portable Memories



Thus summaries can move to higher commands without a complete wired network.

Figure 2-8 An NCO Summarizing
Records from Cards

that he can summarize the records from this lower level of command. His commander in turn can request access to his card to read it into another work station for yet higher level summaries. If the card reader is available at each work station anyway for the reasons described in (1) above, then this additional option is available. This would have some advantages when only a few stand-alone work stations are available at a reserve center or a National Guard center or some field location.

Summary of Scenario Analysis

This chapter has so far presented an analysis of the ACTO mission into a three-person problem, for communication and training, and showed the five types of teaching support systems needed to solve the problem. Two of these five functions, Teacher Quality Assurance and Phase II Training or Future Assurance have not been adequately implemented yet in the Army. One of the major reasons for this lack of successful implementation has been the limits of the current delivery system. The distribution of printed materials and hard copy audio-visual materials is not sufficient to implement these delivery systems in a proper manner. It must be possible to replicate interactions. These interactions can prompt and guide NCO'S in how to train, and can prompt and guide soldiers through training activities, maintenance aiding activities, logistics aiding activities, etc. The new technologies of computer chips and mass portable memories make it possible that interactions and data can be replicated and distributed to the job sites. Thus, it is only recently that there has been an opportunity for adequate teacher quality assurance and future assurance activities to take place.

In fulfilling its mission, ACTO must not only define the technology portions of these new delivery systems (and of the three established delivery systems); ACTO must also consider the roles of the people and the new traditions (both written and unwritten) which must be established to accomplish their mission of "transferring ideas in a way that ensures understanding of meaning and intent." By basing this analysis on the three-person problem for communication and for teaching, it is shown how ACTO's mission can be accomplished. Thus, the new electronic delivery systems being designed by ACTO, augmented by "soft technology" approaches to fit the systems with the people and traditions, can be sufficient to the entire need.

The set of required scenarios can be analyzed against the different types of hardware devices to find a minimal modular set of components. Then the presentation features of that minimal set of components will be elaborated, studied, and recommendations made in the remainder of the report.

BASIC SYSTEM TYPES REQUIRED BY THE SCENARIOS

In order to determine the presentation features required by each of the scenarios presented above, a careful analysis of each scenario and sub-scenario was undertaken. A matrix of sub-scenario by candidate features was prepared. It quickly became obvious that there is a great deal of overlap in the basic system types across the scenarios. For example, an NCO at a battalion learning center who is receiving refresher training would need features identical to those of a student. As another example, the NCO in a battalion learning center who is registering students would need the same capabilities as an NCO at a TRADOC school who is performing the same function. The pattern of candidate features was roughly grouped into five major system types.

This grouping is summarized in Table 2-1. The five types of delivery systems are listed as column headings. Three of the system types are all variations of the basic electronic delivery system for use in a sheltered environment. Thus economy of scale could be gained by having the same basic CPU, memory, and communication hardware and software and plugging in different display, response, and mass memory devices as needed. The militarized electronic delivery system must be rugged and portable. It can be used for job aiding and also occasionally for training, using Extension Training Materials (ETM). Because of its portability and ruggedness it might be used in a variety of training or job aiding applications where a portable rugged workstation is required. An example is the testing and enlistment processing scenario. Testing takes place at mobile evaluation team sites that are rented temporarily for ASVAB testing.

The row headings in Table 2-1 are the various scenarios and sub-scenarios grouped under five kinds of organizational functions explained in this chapter. Either an X or a question mark is indicated in each row under the appropriate column. A single X in a row means that the functions required in the scenario can be fully met by the one support system marked. If a question mark is indicated in other columns this means that a requirement exists for the functions to sometimes take place via a support system other than the primary one. For example, for scenario 5, testing and enlistment processing, the office administration system, a monochromatic graphics and

Table 2-1

FIVE ELECTRONIC DELIVERY SYSTEMS REQUIRED BY THE SCENARIOS

SCENARIO	EIDS WORK STATIONS (SHELTERED ENVIRONMENT)			MEIDS (RUGGED, PORTBL)	HAND-HELD
	1. TRAINING	2. OFFICES & ADMIN.	3. AUTHORING	4. JOB AIDING & OTHER ETM	5. SOT & ARTEP, ETC.
PHASE I TEACHING DELIVERY					
3a Teaching at School	X				
2b Teaching on Units to be used in the field				Y	
2c Two-Dimensional Simulations	X				
LEARNER QUALITY ASSURANCE					
4 Recruiting	X				
5 Testing and Enlist- ment Processing	?	X		?	
1b Upgrading Basic Skills on the Job	X			?	
TEACHER QUALITY ASSURANCE					
Software to Teach and Guide in any Application	X	X		X	Y
MATERIALS DEVELOPMENT					
3b Authoring at TRADOC Schools, ATSC, Etc.	X	X	X		
FUTURE ASSURANCE					
1a NCO Use	X	?			
1b Soldier Use	X			?	
1c Management of Training	X	Y			Y
2a Maintenance Aiding				X	
2b SPA's ETM	X			X	
2c Logistics Control					Y
6a Electronic Office	?	X	?		
6b Command and Control		X			

character display terminal is sufficient to meet all of the requirements specified by the Navy for a system they wish to procure. However, the training workstation with attached videodisc could introduce some more realistic kinds of tests in the future. Also, the portability and ruggedness of the militarized terminal (which also has a monochromatic graphics display) would be suitable for transport to the Mobile Evaluation Team sites for testing. For other rows more than one X is marked. This means that the function required by the scenario needs to take place on more than one of the delivery systems. For example, the function of teacher quality assurance is applicable to every delivery system. In every case there are supervisors and workers who must learn to use the delivery system. Whenever supervisors are placed in the role of trainers then the teacher quality assurance function is important. The delivery systems should have some self-teaching and self-prompting functions built in to them to assure that supervisors can easily train new people in the operation of the equipment. Another area where more than one X is marked is in the management of training. Ratings of individual and group performances in the field must take place on the hand-held unit. However, data collected in the hand-held device from this field activity must be transferred back into either an administrative terminal at the company or battalion level or into the platoon or company level workstations used for training. Further detail on each of the five delivery system types is presented below.

Delivery System 1. Instruction in a Sheltered Environment

Figure 2-9 depicts this system type. Two soldiers are shown working independently at each of two workstations with attached videodisc players and keypads. One of the soldiers might be studying job training materials, another might be taking an SQT test, either for practice or for the record. A small group of five soldiers is shown working around the same workstation with one of them controlling it by means of remote control keypad. An NCO is shown assisting an individual soldier by showing him an actual piece of equipment that is being simulated on the workstation. These workstations may be equipped with their own magnetic memories, or may share a larger magnetic memory, as shown in the figure. Other peripherals may be shown, such as a printer for administrative and communication purposes. This system would be utilized in a TRADOC school and also in the garrisoned units, and in learning centers at the appropriate level.

Delivery System 2. Administration Management in a Sheltered Environment

This system is depicted in figure 2-10. A videodisc player is not required in this application and a color display is not always required, although it would be desirable, especially

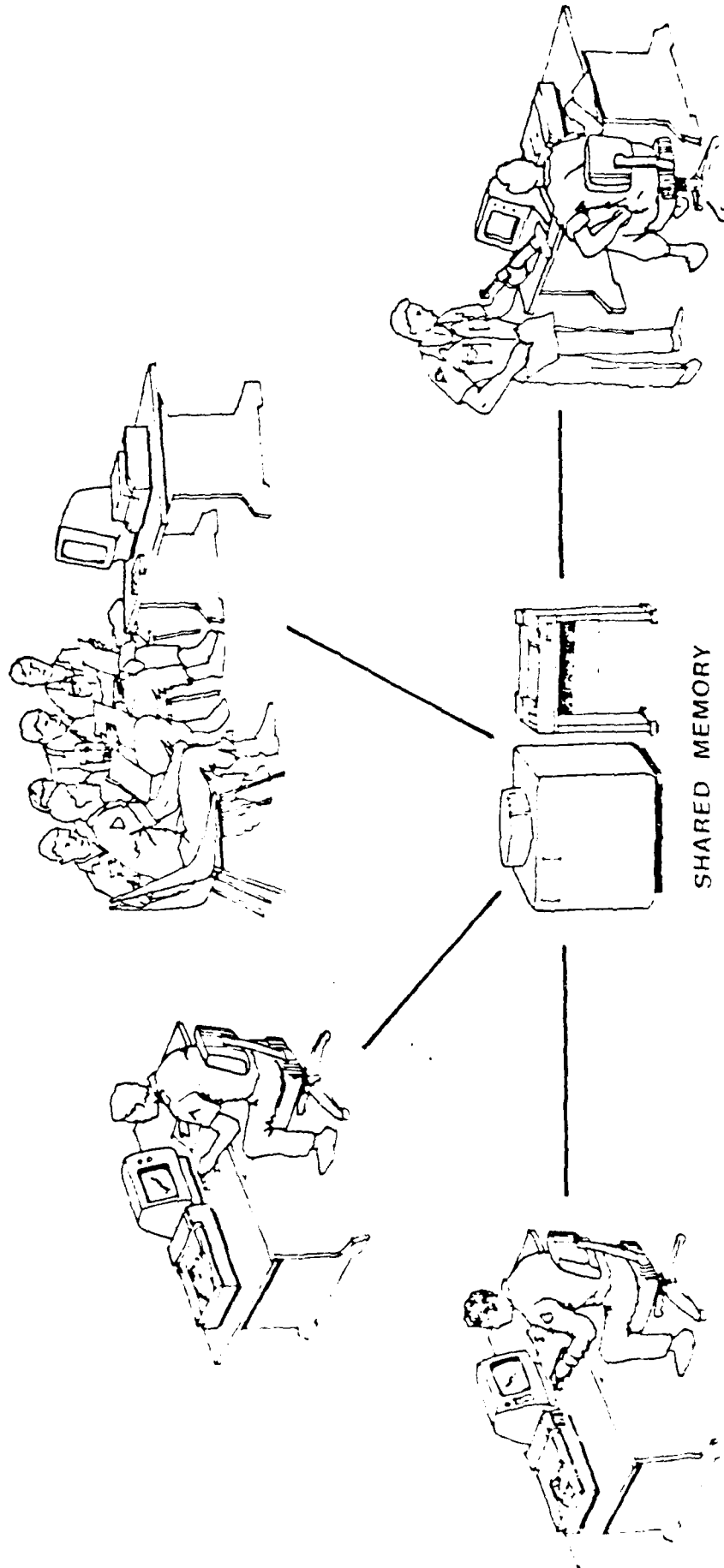


Figure 2-9. Delivery System #1. Instruction in a sheltered environment, with the option of a shared magnetic memory and printer.

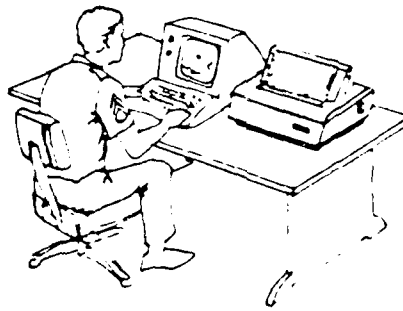


Figure 2-10 The Administrative EIDS

in command and control situations. One of the options to the administrative terminal is the printer shown depicted in figure 2-10. The administrative terminal has application in numerous scenarios.

Delivery System 3. The Authoring System

The main authoring terminal should be the same as the regular Delivery System 1 terminal but with more options. That is, in addition to the videodisc player and the color display, a full keyboard should be provided and a variety of other input devices corresponding to the devices that will be on the EIDS terminals for which the materials are being prepared. Some kinds of authoring only require the administrative terminal. Indeed, it can be said that in the electronic office scenario where communications are being prepared to be sent elsewhere, a kind of "authoring" takes place. Thus the features of the authoring terminal could leverage greatly the work of those preparing the communications. The communications could be prepared in forms other than straight print, requiring some graphics capabilities to speed communications, lower the number of pages, and reduce reliance on the written word.

No illustration is provided for the authoring station, but the basic processing and communication components would be the same as those illustrated for the training and administrative delivery systems.

Delivery System 4. Job Aiding in the Field

This delivery system is illustrated in Figure 2-11. It is packaged in a small attache case-sized unit. A flat panel monochromatic graphics display is visible. A hand-held remote control keypad communicates with the system to call out the pages of SPA's material to aid in the particular maintenance task.

Delivery System 5. The Hand-Held Record Keeping System

Figure 2-12 shows an NCO rating each of the sub-tasks on an ARTEP as soldiers in his unit perform one of the sub-tasks. The hand-held unit must be capable of displaying short prompts to the NCO that guide him in the sub-task being rated. This same hand-held unit could be used for inventory and logistics control applications. The soldier using it would be prompted by statements to locate and identify certain items and would enter the number found into the local memory.

Together, these five system types were found to encompass virtually all of the candidate features for the scenarios which are described in the storage media report, and as augmented herein. These five system types are used in the cost analysis reported in chapter 8.

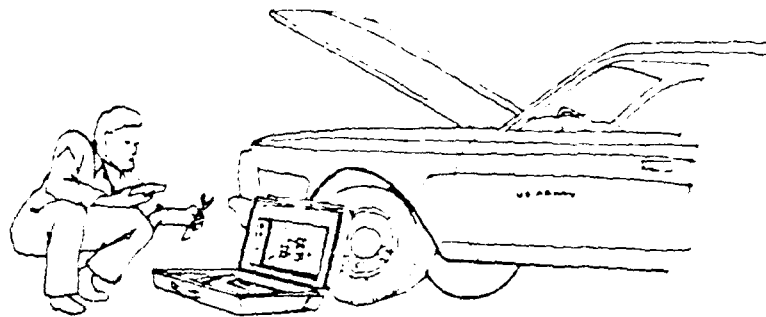


Figure 2-11. The MEIDS delivery system for SPAS job--aiding and for other applications where easy portability and ruggedness are required.

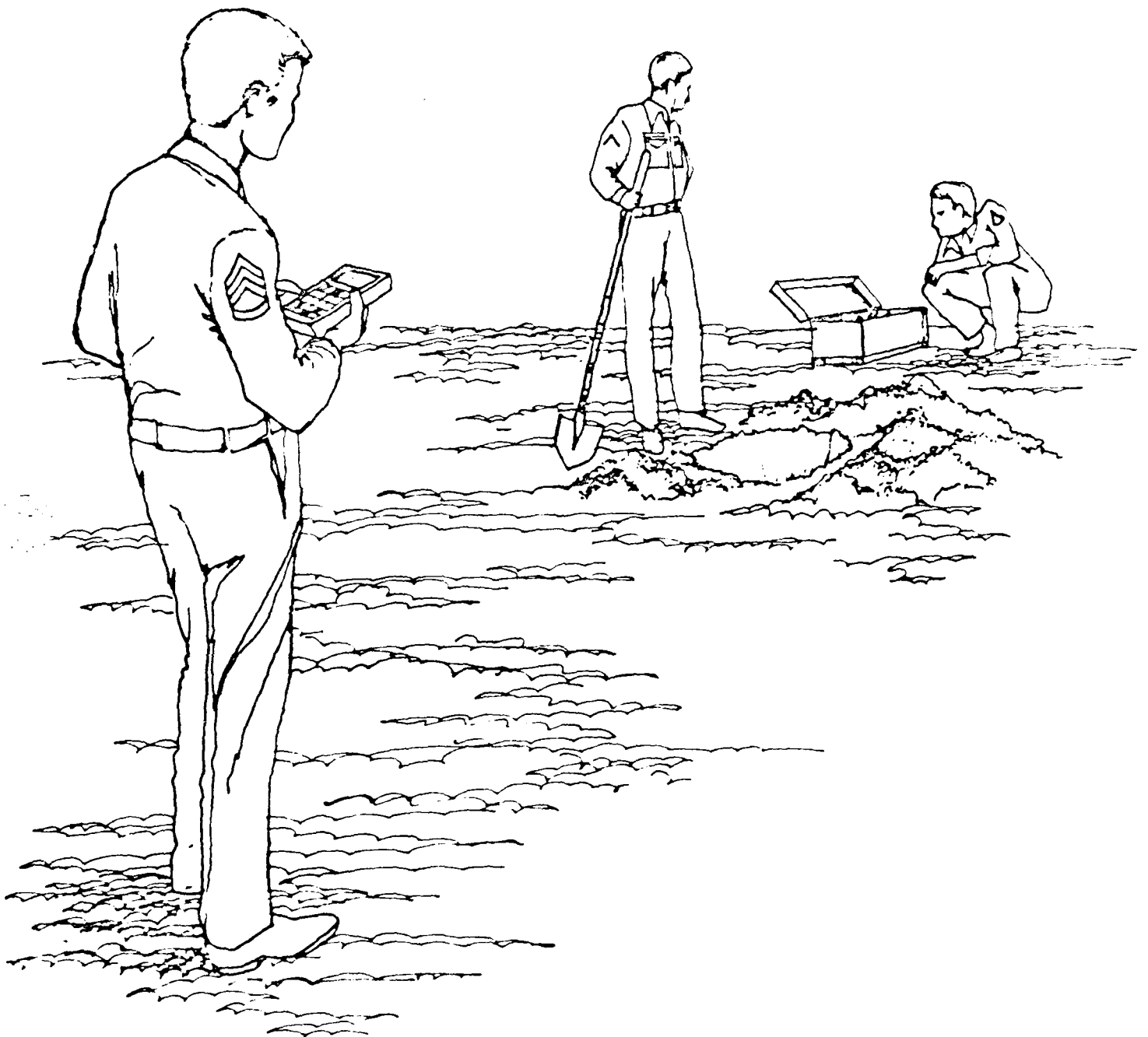


Figure 2-12. Use of the Delivery System
48, the hand-held prompting and recording
system.

CHAPTER 3

INSTRUCTIONAL DESIGN CONSIDERATIONS FOR PRESENTATION FEATURES

This chapter will present subsections for each of the following major presentation feature topics:

- I. Visual Elements and Graphics
- II. Color, Shading and Gray Scale
- III. Motion, Animation and Still Frames
- IV. Sound and Voice Input and Output
- V. Interaction Processes

For sections I-III the results of several major reviews are summarized. These reviews concern the use of visual, graphic, color, and motion presentation features. The reviews are Dwyer, 1971, 1978, 1980; Gulliford, 1973; Merrill and Bunderson, 1979; and Moore and Nawrocki, 1978. A summary statement is presented first for each section, followed by the guidelines and the supporting research.

SECTION I. VISUAL ELEMENTS AND GRAPHICS

The major point from the reviews on realism and visual elements is that meaningfulness is more important than realism--hand sketched line drawings which highlight critical points can be as effective as detailed colored pictures. The critical factor appears to be the match between the graphic and the learner's relevant knowledge. Simple line drawings are appropriate for those who are new to a subject area and are being externally paced through instruction (e.g., by a videotape). Too much detail in too little time can impede learning by obscuring the major points. Conversely, for learners who are already experienced in the content area, who are visually literate in graphics conventions, and who can self-pace at their own speed, more detail gives real world experience finding critical features on their own. In this case more realism is appropriate.

- Visualization containing too little or too much realistic detail may lead to negative motivation on the part of the student. Effective visualization contains sufficient information to encourage active student participation without simultaneously interfering with his/her attending to the stimuli (Dwyer, 1980).
- The array of different types of available visualization represents increasing degrees of realistic detail (from line drawings to realistic photographs). Excessive realism in a visual map impede rather than facilitate optimum student achievement--the visual map contain so many stimuli that the students are unable to focus their perceptual energies long enough or clearly enough to engage in the kind of interaction necessary for th

desired kinds of learning to occur. Consequently, a photograph of an object or situation may present a "perfect" image of reality but may fail to clearly illustrate that part of the message to be communicated (Dwyer, 1980).

- Different types of visuals (containing varying amounts of realistic detail) can provide the learner with the same information without providing the same amount of stimulation. Consequently, two different types of visuals may have the same instructional potential for facilitating student achievement. Operationally then, differences in the amount of realistic detail contained in visuals has to make a difference to be a difference. Visuals are functionally identical if they are indistinguishable in terms of improving student achievement (Dwyer, 1980).
- The process of simplifying or editing realistic detail from visuals may reduce or eliminate important characteristics prerequisite for learning to occur. It must be possible to distinguish relevant from irrelevant aspects of an object or situation. An edited visual may provide a too narrow perspective of reality where the student is less able to recognize necessary patterns essential in making meaningful interpretations. Editing or simplifying realistic detail beyond a certain point does not lead to uniformity of perception (Dwyer, 1980).
- The relationship between the amount of realistic detail in visuals and student achievement is curvilinear rather than linear. There are points beyond which increases in the amount of visual stimuli in visuals impedes rather than facilitates learning. For this reason the amount of stimuli in visuals should probably be thought of in optimal rather than maximal terms. There is an optimal level beyond which adding additional realistic detail provides no further increases in learning. (Dwyer, 1980)
- The advantages and disadvantages inherent in different types of visuals need to be identified and isolated functionally in relation to their relative contributions in facilitating specific kinds of learning. Only when this has been achieved it is possible to effectively manipulate and integrate the different types of visual materials to ensure that the ones being used are the ones which will produce optimum learning. (Dwyer, 1980)
- The realism continuum for visual illustrations is not an effective predictor of learning efficiency for visualized instruction which is externally paced. (Dwyer, 1978)
- Visual illustrations containing different amounts of realistic detail can transmit the same amount of information without providing the same amount of visual stimulation. (Dwyer, 1978)

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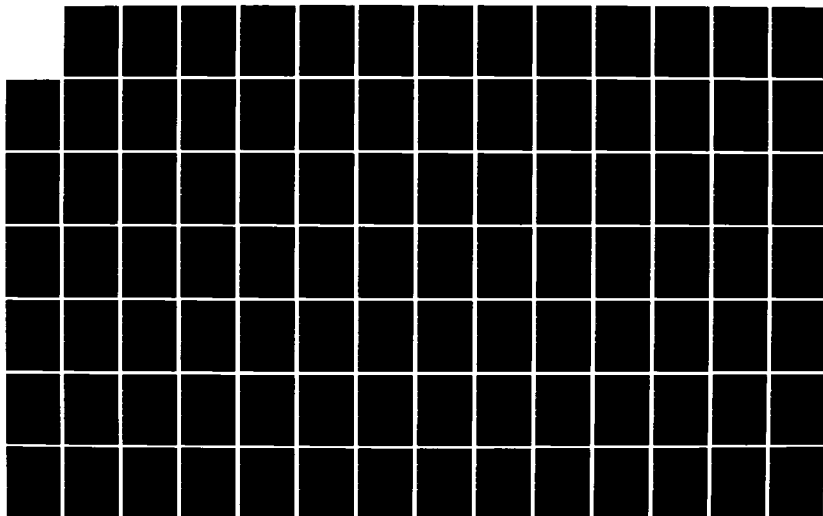
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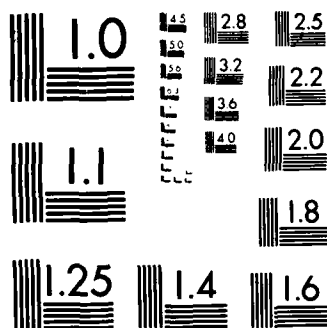
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MICROCOPY RESOLUTION TEST CHART
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- To reduce the effects of individual differences in learning from visualized instruction both simple and detailed line drawings are more effective than photographs. (Dwyer, 1978)
- The instructional effectiveness of a specific type of visual is related to the number of relevant cues present--either too many or too few cues affect learning adversely. (Dwyer, 1980)
- Simplified line drawings are often more effective than complex photographs for instructional purposes. (Moore and Nawrocki, 1978)
- A line drawing appears to be as good as a realistic presentation...using line drawings to represent items results in faster, longer retained learning. Increasing realism in a visual does not always cause a significant increase in learning. Since we learn from the boundaries of shape, providing total realism seems to be unnecessary... A learner should not have to discriminate between relevant and irrelevant details. (Gulliford, 1973)
- Graphics are not necessary and may actually be distracting if they are used as signs for concepts, objects or events with which the learner has had considerable previous experience. Under such conditions, the added external visual or graphic is redundant with the learner's mental visual image, and thus may not facilitate performance. Graphics become helpful and vital when the learner is exposed to new concepts, objects, or events for which he has no labels and/or corresponding visual images. (Merrill and Bunderson, 1979)
- Pictures, color, realism, and motion generally increase the attraction and interest value of materials, are preferred by learners of all ages, and may significantly reduce attrition from training courses. (Merrill and Bunderson, 1979)
- Simple line drawings, color or black and white, appear to be the most effective type of graphic for increasing achievement. (Merrill and Bunderson, 1979)

Method of Presentation

- There is a relationship between how visualization is presented to students and amount of student learning that will occur. The types of visuals most efficient and suitable for the rapid transmission of information (externally-paced instruction) are not the ones most effective in facilitating optimum amounts of information in a self-paced instructional format. Simplified line drawings (black and white and color) were more effective for rapid transmission of externally paced instruction. Colored realistic photographs were most effective for self-paced instruction (Dwyer, 1980).
- When complex visuals are used in the instructional process, the student needs adequate time to make the proper perceptual discriminations (Dwyer, 1980).

Level of Educational Objective

- No single type of visual can be identified as being most effective in facilitating student achievement of all kinds of learning objectives. Many of the conditions of learning are specific to a particular medium, to a specific type of educational objective, to a particular type of student, etc. (Dwyer, 1980)
- There are some types of learning tasks for which increased learning cannot be enhanced by the use of visuals (e.g., verbal information). (Dwyer, 1980)

Visual Testing

- When visualized instruction has been properly designed and employed, visual testing provides a more reliable and valid assessment of the students' level of content acquisition. (Dwyer, 1980)

Individual Differences

- Specific individual difference variables are important instructional variables (age, I.Q., prior experience, reading comprehension) which determine the effectiveness of different types of visualization. For example, learners being exposed to a new content area would profit optimally from line drawings whereas individuals more familiar with the content area would profit from the more realistic types of illustrations. (Dwyer, 1980)
- Some types of visuals (e.g., simple line drawings) are effective over a wide range of audiences, methods of utilization and types of educational tasks. (Dwyer, 1980)
- There are individual preferences and learning abilities for visual and verbal modes of instruction. (Moore and Nawrocki, 1978)

Learning Preferences

- Visuals and color are generally preferred to black and white. (Moore and Nawrocki, 1978)
- Visual multi media systems can reduce attrition. (Moore and Nawrocki, 1978)
- A learner control system which allows students to select that treatment which would be most appropriate for them at a given point of time may be more effective than assigning students with different abilities to a small number of alternate treatments. (Merrill and Bunderson, 1978)

Attention and Cueing

- The ability to focus one's attention on relevant cues in a learning situation is fundamental to all learning. For a visualized presentation to achieve maximum instructional effectiveness efforts have to be expended initially to attract the student's attention and then to sustain the attention over extended periods of time. (Dwyer, 1978)
- Maximum learning from a visualized presentation may depend on the judicious juxtaposition of several different types of cueing techniques rather than the simple nature of the visual stimuli contained within the visualization itself. (Dwyer, 1978)

Instructional Content

- Visuals are better than verbal stimuli for recognition and recall tasks. (Moore and Nawrocki, 1978)
- Visuals and color are useful when the learning task requires a visual or color based response. (Moore and Nawrocki, 1978)

Instructional Design

- The relationship of the timing of occurrence of (instructional) events is of more crucial importance for effective learning than beautifully prepared materials. (Gulliford, 1973)
- The general conclusion that emerges is that more often than not, there is no learning advantage to be gained by a fancier, more complex treatment. (Guilliford, 1973)
- Interactive, dynamic, computer graphics offer a unique but largely unknown training application potential. (Merrill and Bunderson, 1978)

Bretz (1971) has identified four guidelines for determining whether or not to use visualization in instruction:

- Is visual recognition and identification of objects, signs or symbols other than language symbols an objective of the lesson or required for job performance?
- Is the recognition or recall of a procedure, the physical actions or positions of which are unfamiliar to the learner, one of the objectives of the lesson?
- Is the understanding of two-dimensional physical or spatial relationships an objective?
- Is the recall or recognition of the three dimensional structure of some physical system or object required?

Merrill and Bunderson (1979) also provide the following specific guidelines for various types of training objectives:

- Rule learning and using. The learning of complex procedural rules can be facilitated through the use of representations such as flow charts which graphically portray the order of the operations of the procedure and alternate paths which could be taken at decision points.
- Classifying. Pictorial graphics should be used as examples of concepts which have concrete referents. In the initial stages of training, simplified pictorial graphics should be used in order to isolate and highlight critical attributes. Later stages of training could employ more realistic graphics in order to facilitate transfer to the real world environment or task.
- Identifying symbols. Considerable drill and practice with corrective feedback using graphics of actual symbols may be required in order to learn adequately how to identify symbols.
- Detecting. The training of detecting behavior should involve the presentation of graphics within significant blocks of time and space which are realistic in terms of both the object itself and the natural noise of the environmental setting.
- Making decisions. Training in decision making should involve instruction in the use and interpretation of various numerical relationships represented in both tabular displays and figural graphics.
- Recalling bodies of knowledge and using verbal information. A graphical representation of the relationship between various facts and ideas can provide organization and using which may facilitate the storage and retrieval of verbal information. Pictures or line drawings inserted in textual, verbal information often have no effect on performance since they only illustrate concepts which could have been readily visualized from the textual description.
- Performing gross motor skills. The demonstration of a complex motor skill in real time may be too fast. However, slow motion could demonstrate the continuity of the movements while permitting critical aspects to be perceived. A videotape of a trainee's motor skill performance may be a very valuable feedback device.
- Steering and guiding-continuous movement. Graphics used to present the relevant cues for steering and guiding behavior should have a high relationship to real world noise and time conditions in the later stages of training.
- Recalling procedures, positioning movement. If the procedure to be learned involves the assembly or disassembly of a piece of equipment with many parts, then graphics would be necessary to show the various parts of the equipment and their relationship to each other.

- Voice communicating. In general, graphics would not be necessary in the training of voice communicating behavior.
- Attitude learning. Human modeling seems to be the most applicable, and probably the most effective approach for attitude learning. Attitude learning involves the imitation of a credible and respected human model's choices of action. A human model may be presented in several ways: appearing in person, in pictures, in movies or TV, or merely described as in a novel, history text, or biography.

1.2 SUPPORTING RESEARCH ON VISUALS AND GRAPHICS

Realism in Learning

A major issue in the media literature is whether greater degrees of realism in the presentation improve learning. Francis Dwyer (1971, 1978) has conducted a systematic and exhaustive study of this issue. The results of his work suggest that realism does not necessarily improve learning performance and that simple line drawings are sometimes superior to photographs or a detailed line drawing. Other research studies have also shown that less realistic visuals are often very effective in instruction and training (Borg and Schuller, 1979; Wicker, 1970; Paivio, Rogers, and Smythe, 1968; Morgan, 1971; Wheelbarger, 1970; Hagaman, 1970; Gorman, 1973).

A study by Borg and Schuller (1979) illustrates this point in the context of TEC lessons. Borg and Schuller compared the achievement and attitudes of Armor Crewmen (MOS 113) on two versions of a lesson for tank boresighting. One version was the original TEC lesson and the second was prepared with much simpler graphics. The results showed that there was no difference in terms of either achievement or attitudes suggesting that simpler art in TEC lessons would be equally effective and acceptable.

Markham (1979) replicated Borg and Schuller's experiment using the same TEC lesson but with even simpler, hand-drawn artwork. He used both reserve soldiers and college students. His results confirmed the finding that no performance differences could be found between the simple and complex artwork.

One problem with this general conclusion is that the criterion measures in the experiments have almost always been paper and pencil or visual identification rather than actual performance tests. It may be that realistic presentations do not improve performance on paper but might with actual equipment. For example, Wager (1980) provided cardiopulmonary resuscitation (CPR) training in the form of text, films or actual demonstrations

and then rated the students on their ability to perform CPR. The film and live demonstration group performed better than the text group although none of the groups were able to perform CPR satisfactorily as a result of their presentations.

Experiment 1 herein dealt with this issue and found no important differences in performing a cable assembly task, between line drawings and colored pictures presented via videodisc. It also found a speed (but not accuracy) advantage to training and testing using the same type of presentation for training as for testing. The data thus indicates that line drawings vs. colored pictures is not a critical factor, even in a performance task.

There are a number of conditions which enhance the effect of high realism in visuals. First, realistic visuals are more effective in self-paced instruction when the learner has control over the rate of presentation (Dwyer, 1975). Second, the effectiveness of a highly realistic visual depends in part on the number of relevant cues accessible to the learner within the visual (Dwyer, 1980). Third, color helps to augment the effect of realism (Dwyer, 1980, 1967, 1968, 1969). Fourth and possibly most important, sufficient time to adequately process the realism must be allotted (Dwyer, 1978; Dwyer, 1980).

The foregoing suggests that highly realistic displays, such as photographs, models or real objects, can confront a learner with too much stimulation too quickly. If the learner is not given enough time to process the information or is not initially directed to relevant aspects of the complex graphic the graphic could reduce learning. There is also a motivational aspect of high realism which mitigates the learner's difficulty in processing these graphics. For example, young children initially prefer simple line drawings, but after the 5th grade they begin to prefer more complex visuals and photographs by a ratio of 85% to 15%. Younger children do like illustrations of the familiar, but as they grow older they like complex visuals of the unfamiliar more. Adults lack interest in photographs which are of new or unfamiliar material, especially when they are ambiguous (Spaulding, 1955). Students prefer to look at more complex visuals (Myatt and Carter, 1979). They also will attend to complex visuals for longer periods of time. Thus, the motivation related to visual realism will help a learner to "stay with" the visual, but the visual can overwhelm the learner if it is improperly utilized.

Pictures

Research has also shown that pictures can improve instruction in elementary reading (Peeck, 1974), high school mathematics (Rasco, Tennyson, and Boutwell, 1975), high school and college biology (Dwyer, 1967, 1968) and military fire fighting (Sellman, 1972). A recent review of twelve research studies by Levine and Lesgold (1978) has shown that pictures can facilitate prose learning.

Line Drawings

Several researchers recommend that highly realistic visual presentations be edited of all irrelevant cues and the redundancy of the relevant cues increased to ensure better learning. They make a case for extensive use of the line drawing, a visual which contains only the essence of the realistic situation (Levie and Dickie, 1973; Black, 1962; Travers, 1967; Dwyer, 1978). Line drawings have proven to be an effective means of visual instruction a number of times, especially in presentations which are externally paced (Attneave, 1954; Dwyer, 1967, 1968, 1969, 1971, 1976; Moore and Sasse, 1971; Rusted and Coltheart, 1979; Borg and Schuller, 1979; Carpenter, 1954; Lumsdaine and Gladstone, 1958; May, 1965).

One important effect of the line drawing is to reduce the difference between students of different reading levels (Parkhurst, 1976). Line drawings appear to be very useful for initial learning of concepts (Ryer and Schwartz, 1965). It has also been found that children can reproduce a drawing by portraying a skeleton of it, but cannot reproduce details (Travers and Alvardo, 1970).

Visuals in Externally Paced vs. Internally Paced Instruction

Research summarized by Dwyer (1978) has shown that different visuals are effective for alternative methods of presenting visualized instruction. In externally paced instruction (e.g., lectures, films, slide-tape, movies) where the learner has little control over the pace of instruction, the simplified line drawings in black and white and color were most effective for the visual identification and drawing tests. No differences between the visual and no visual conditions were found for the terminology and comprehension tests. Color also enhanced the line drawings for both simple and detailed line drawings. Realistic photographs were the least effective visuals for externally paced instruction. See Table 3-1.

Table 3-1

EFFECTIVE VISUALS FOR EXTERNALLY PACED INSTRUCTION

<u>Task</u>	<u>Most Effective Visuals</u>	
	<u>Slide-Tape</u>	<u>TV</u>
Terminology	No visuals	No visuals
Identification	Simple line drawing	No visuals
Drawing	Simple line drawing	Simple line drawing
Comprehension	No visuals	No visuals
Total criterion	Simple line drawing	No visuals

In internally paced instruction (e.g., programmed instruction where the learner has considerable personal control over the pace of instruction), black and white and colored photographs were the most effective type of visuals. See Table 3-2.

Table 3-2

EFFECTIVE VISUALS FOR INTERNALLY PACED INSTRUCTION

<u>Task</u>	<u>Most Effective Visuals</u>
Terminology	Text without visuals
Identification	Realistic photographs
Drawing	Realistic photographs
Comprehension	Text without visuals
Total criterion	Realistic photographs

In studies comparing visuals in externally paced vs. internally paced instruction (Dwyer, 1973a,b), the results show that photographs and three dimensional models were most effective for internally paced instruction, while simple and detailed line drawings were most effective for externally paced instruction. A second study also showed that photographs, detailed line drawings and three dimensional models were most effective for internally paced instruction while simplified line drawings were most effective for externally paced instruction.

In summary, simplified visuals are more effective if the instructional pace is externally (teacher) controlled. Realistic photographs and models were more effective if the instruction is internally (student) controlled. Color can effectively enhance visuals for both externally and internally paced instruction. Visuals were also more effective for achievement tests requiring a visually related response.

Visual Preferences

Research has shown that both children and adults prefer instruction with color and visuals over black and white and non-visual instruction (Dwyer, 1978; Chute, 1979; Johnson and Roberson, 1979; Lamberski, 1980; Gulliford, 1973; Merrill and Bunderson, 1979; Myatt and Carter, 1979; Simonson, Thies, Burch, 1979).

SECTION II. COLORII.1 Color Guidelines

- There is substantial evidence which attests to the fact that the judicious use of color in visuals is a viable instructional variable in improving student achievement of specific educational objectives. (Dwyer, 1980)
- Varied methods of cueing visualized instruction can be used to heighten student interest and enthusiasm; however, constant repetition of a single type of cueing technique may quickly produce disinterest and boredom. (Dwyer, 1980)

- The inappropriate use of visual materials or gimmicks in the teaching-learning process may actually distract learner attention from essential learning cues and depress subsequent achievement. (Dwyer, 1980)
- All attention gaining cueing strategies are not equally effective in increasing student achievement. (Dwyer, 1980)
- (Visual and color) cues can be effectively employed to facilitate student achievement of specific educational objectives. (Dwyer, 1980)
- In general, color has little demonstrated effect on performance but may enhance learning when used to emphasize relevant cues and when actual color discrimination is required. (Merrill and Bunderson, 1979)
- Color is an effective instructional cueing device. (Moore and Nawrocki, 1978)
- The addition of color does not intrinsically increase achievement. However, color can enhance achievement of specific instructional objectives. (Moore and Nawrocki, 1978)
- Color materials are generally preferred to black and white. (Moore and Nawrocki, 1978)
- Color is beneficial for tasks which require a color-based response. (Moore and Nawrocki, 1978)
- Research has found that people prefer to receive and interact with presentations that occur in color. (Dwyer, 1978)
- Color interests children, but there is no evidence that it helps them learn. For older persons, the studies report an apparent lack of color affecting learning. However, there is evidence that it reduces the rate of forgetting on long term retention tests. Adults consistently prefer color. (Gulliford, 1973)
- Changes in brightness, intensity or color are important for sustained attention, sensitivity and normal functioning. (Gulliford, 1973)

II.2 SUPPORTING RESEARCH ON COLOR

The literature seems fairly conclusive on the fact that color does not always improve learning, although it may result in slightly better retention (Allen, 1971; Chute, 1979) and almost always is preferred over black and white presentations. However, it appears that there is a difference between the use of color in motion presentations such as film or TV and static

presentations such as slides or print. The use of color in motion presentations (where it is often confounded with realism) does not result in significant performance gains. For example, Kanner and Rosenstein (1960) and Rosenstein and Kanner (1961) conducted two extensive studies with videotape using soldiers as subjects. They compared color versus black and white lessons along with verbal cueing and found no advantage for the color. They concluded that labeled cues in black and white were as effective as color cueing.

For static presentations, color may have some advantages over black and white. For example in Dwyer's studies, colored versions of line drawings were consistently more effective in facilitating student achievement across all criterion measures. Berry (1977) found that while both realistic and nonrealistic color cueing in slides resulted in significantly more recognition than black and white on an immediate test, only the non-realistic color cueing resulted in significantly better recognition on a delayed test. This result suggests that color may not improve immediate learning but may affect retention.

A significant learner variable which has consistently been identified in this line of research is the interaction of aptitudes with color. Generally color is more effective with high aptitude learners (Allen, 1975). For example, Chute (1980) showed color and black and white versions of a film to students with high and low spatial aptitude. On both immediate and delayed tests, the low spatial aptitude students scored better with the black and white version. The difference was greatest for the delayed test. This clearly has implications to Army training. Moore, Nawrocki and Simutis (1979) have suggested that the effectiveness of graphics may vary with an individual's spatial aptitude. See also Kozlowski and Bryant, (1977).

There are two pragmatic considerations which mitigate the research results on color. The first is that the predominant mode of media today is color. Whether it makes any measurable difference in performance or not, students are used to, and expect color presentations. Color appears to have strong affective appeal as indicated by the fact that most people prefer to watch color presentations.

The second pragmatic consideration is the wide range of color quality found in television receivers in actual use, either as a property of the equipment or poor tuning by the user. It seems somewhat ridiculous to carry out research on the precise qualities of color for TV viewing when the actual quality of the color will vary so greatly in delivery. This consideration applies much less to slides or film where the delivery quality is much more uniform.

Color and Affect

The preponderance of evidence shows that colored materials are preferred over non-colored materials (Malter, 1948; VanderMeer, 1952, 1954; Kanner and Rosentein, 1960; Link, 1961; Rosenstein and Kanner, 1961; Miller and Booth, 1974; May and Lumsdaine, 1958; English, 1961; Scwietzer, 1963; Travers, McCormick, and VanMondfrans, 1964; Jones, 1965; Chu and Schramm, 1967; Dwyer, 1972; Lamberski, 1972; Katzman and Nyehuis, 1972; Scarpino, 1972; Puig, 1976; Chute, 1978; Gibson, 1974; Johnson and Roberson, 1979; Chute, 1979; Winn and Everett, 1978; Zuckerman, 1954). In addition, two comprehensive reviews of color research cite a number of studies which support the claim that colored materials are favored by learners over non-colored materials (MacLennan and Reid, 1967; Bretz, 1970). It has been shown that young children specifically display a preference for interaction with visual materials that contain color (MacLean, 1930; Long, 1945; Rudisill, 1952; French, 1952; Katzman and Nyehuis, 1972). The preference for color among learners extends from its use as a coding device to its decorative use. The research confirms a common sense notion that colored materials are more interesting and widely preferred.

Color has a definite physiological effect on perceptual mechanisms and can be attributed as the cause of various emotional reactions (Goldstein, 1942; Cheskin, 1948; Kouwer, 1949; Rudisill, 1952; Collier, 1957; Gerard, 1958; Smith, 1958; Birren, 1959; Schwartz, 1960; Rusenheim, 1967; Child, 1968; Nourse and Welch, 1971; Plank and Schick, 1974; Bornstein, 1973; Chute, 1978; Adkinson and Berg, 1976; Bornstein, Kessen and Weiskopf, 1976). Color is more emotionally engaging for a learner (Winn and Everett, 1978; Ditcher). Scanlon (1967) reports that color "alters the importance of the spoken word." He also observed that color helps viewers become more involved in the instruction and less passive.

The significance of preference is established only if it can be shown that the preference leads to increased attention or motivation which in turn leads to increased achievement. A number of studies have shown that color preference is related to an increase in learner motivation and sometimes increases in achievement (Ingersoll, 1970; Farr, 1971; Kalin, 1972; Lilly and Kelleher, 1973; Daniel and Tacker, 1974; Burke Marketing Research, 1960; Kumata, 1960; Gallup and Robinson, 1965; Schaps and Guest, 1968; Schwerin, 1957; May and Lumsdaine, 1958; Birren, 1963; Dooley and Harkins, 1970; Dwyer, 1972, 1976a; Schramm, 1972).

However, it must be noted that there are some studies which contradict the claim that preference is correlated with attention and achievement, many researchers having expressed reservations about the relationship of preference to achievement (VanderMeer, 1954; Dwyer, 1972, 1976b; Travers, 1970; Twyford, 1951). These researchers do not deny that color might have an effect on

achievement but they do point out that there is no necessary relationship between the two. Lamberski (1980) notes that studies relating color and achievement in general which result in color being ineffective may be using color inappropriately, namely as peripheral or of low associative value. He summarizes this claim saying, "color-code is a sufficient attention-getting strategy producing measurable effects on cognitive learning which cannot be accounted for by purely words or labels" (p. 108).

The research conclusively shows that color is the preferred state of the instructional medium by learners. The attractiveness, variability, and complexity of color in visual materials serve as an interest gaining device which leads to attentive behavior which in turn is more likely to result in increased performance. Color-coding serves to simplify and categorize information for the learner and thus enables him to focus his attention on the relevant.

Literature reviews on color often illuminate contradictory findings and that leads to a stalemate of beliefs about the impact of color on learning and performance. There are several reasons for the inconclusiveness of the findings. First, the use of the variable has not been properly executed in experiments related to achievement (Lumsdaine, 1963; Lamberski). This can explain why many studies using color in instructional materials have failed to show any significant difference and unless the color directly relates to the instruction adding color does not lead to increased achievement (Dooley and Harkins, 1970; MacLean, 1930; Gibson, 1952; VanderMeer, 1952, 1954; Levie and Dickie, 1973; Johnson and Roberson, 1979; Zuckerman, 1954; May and Lumsdaine, 1958; Kanner and Rosenstein, 1960; Kanner, 1961; Katzman and Nyenhuis, 1972; Kanner, 1968; Travers, 1967; Reich and Meisner, 1976). Many of the reviews of the late 1960's were skeptical about the benefits of using color in instructional materials (Kanner, 1968; Lumsdaine, 1963) and possibly the reason for that skepticism was related to inappropriate experimental questions and research designs.

Recall

Color-coding has shown positive effects on immediate and delayed recall (VanderMeer, 1952, 1954; Lamberski, 1972, 1975; Kauffman and Dwyer, 1974; Scull, 1974; Hoban, 1975; Farley and Grant, 1976; Berry, 1977; Lamberski, 1980). Successful recall is dependent on a number of other variables including age, time of interaction, and attentiveness (Dwyer, 1972a; Frechtling, 1970) but the use of color as a coding device seems to have a great impact on recall in visual and spatial tasks (Otto and Askov, 1968; Dwyer, 1972a; Reich and Meisner, 1973; Shaw, 1975).

There is a substantial body of research that shows that color enhances recall on paired associates tasks (Committee on Colometry, 1954; Weiss and Margolis, 1954; Peterson and Peterson, 1957; Underwood, Har and Ekstrand, 1962; Berry, 1969; Goodman,

1975; Buchanan, 1975; Isaacs, 1966; Swede and McNulty, 1967; Otto and Askov, 1968; Corballis and Luthe, 1971; Arnold and Bower, Bower, 1972; Newby and Young, 1972; Light, Berger, Bardales, 1975; Petrich and Chiesi, 1976; Winn, 1976, 1977; Green and Anderson, 1956; Bourne and Restle, 1959; Salz, 1963).

Schontz, Trumm, Williams (1971) showed that color helps retrieval under the following conditions:

- (a) there are many categories of information,
- (b) the number of concepts per category is small,
- (c) the colors used are highly discriminable.

Using color under such conditions will lead to better recall.

Perceptual Tasks

Color facilitates performance in a number of perceptual tasks such as counting, searching, discrimination, locating, and recognizing. A very clear-cut finding is that if a target object has a unique and pre-designated color coding known by the individual, then color definitely aids in the identification of that object. For target identification involving photographs, color showed a 29% advantage over black and white (Markoff, 1972). In identification tasks color is a superior code to coding by size, by brightness, and by shape. Color is not superior to alphanumeric coding, however (Christ, 1975). When a subject is using a display where targets are chromatically characterized, adding color to the display interferes with the subject's ability to identify the proper target. This interference occurs whether the color is central to the target or not. In a search task, color is the best advice for coding over size, brightness, shape, and alphanumeric. In fact, color ranges from a 40% to 63% savings in search time over these other types of codes. The results hold for both older and younger individuals (Lamberski, 1980).

Higher Order Cognitive Tasks

There is proportionately less research done in the area of color affecting higher cognitive tasks. Color-coding during concept acquisition may enhance subsequent learning (Lamberski, 1980). Subjects having color-coded instructional materials did better on tests for comprehension and terminology than those having black and white (Lamberski, 1980). Other studies show that color coding used in active self-paced materials (books, posters, etc.) has no effect on concept-learning (Travers, et al., 1964; Rusted and Coltheart, 1979; Scarpino, 1970; Dooley and Harkins, 1970; Scull, 1974).

Learning rates and performance were better in learning phonic materials and beginning reading when color coded materials were available in the form of underlining, shading, etc. (Gattegno, 1962; Cruickshank, 1967; Jones, 1968; Bannatyne, 1966; Knafle, 1974; Lyczak, 1976; Hinds and Dodds, 1968). Color facilities in dramatic portrayal (Reich and Meisner, 1973). Color also helps in tasks which require the perception of movement (Travers, 1969).

Color Coding

Research shows that color can be used as an effective instructional coding device. Color coding is often as effective or more effective than other coding devices. The superiority of color coding over number, shape and alphanumeric coding is well established for location-search and/or counting tasks (Christner and Ray, 1961; Hitt, 1961; Jones, 1962; Christ and Corso, 1975; Christ, 1974, 1975; Barker and Krebs, 1977; Brooks, 1965; Dyer and Christman, 1965; Green, Mitchell and Jenkins, 1953; Heglin, 1973; Smith, 1962; Shontz, Truman, and Williams, 1971; Green and Anderson, 1956). Color coding also reduces reaction times and errors for whatever task is being performed (Semple, Heapy and Conway, 1971; Jones, 1962; Reed, 1951; Burnette, 1970; Christ and Teichner, 1973; Smith, 1973; Kopala, 1979; Wolfe and Zigler, 1959; Reed, 1951).

Christ (1974, 1975) reviewed 43 studies on the use of color code vs. achromatic codes and came to the conclusion that color coding is definitely superior to other codes under some conditions, but can be detrimental under others. It is not wise to suppose that color coding is universally effective. At times color coding may serve as "noise" when it is irrelevant or overly dominating. Color is particularly harmful on some identification tasks (Aliusi and Muller, 1958; Barker and Krebs, 1977; Hitt, 1961). On some other tasks color had little effect (Levie and Dickie, 1973; Kanner, 1968; Travers, 1967) and in other (e.g., comparing, verifying) no type of code was helpful (Barker and Krebs, 1977). However, the importance of color coding in organizing information (especially with dense displays), helping discrimination, and facilitating locating are all significant advantages.

The potency of color varies with the display density. For very dense displays color does not have a facilitating effect and at the same time for very sparse displays color offers no advantage. Thus, the usefulness of color does vary with the density of the display, its optimum effect lying somewhere between very dense and very sparse displays (Christ, 1975). Smith (1963) showed that as display density increased from 20 to 100 items, using a color code reduced search time over black and white code by 45% to 70%. Similarly, on a counting task for the same range of density, color coding reduced the time on the task by 63% to 69%. The effectiveness of color coding as a function of

display density would seem to show a curvilinear effect for its superiority over achromatic coding.

When the display is simple and uncluttered any particular code will make little difference in performance. However, as the display becomes complex and dense, color has an overwhelming advantage over any other code (Christ and Corse, 1975; Linton, 1975; Wolf and Zigler, 1959; Green, McGill and Jenkins, 1973; Heglin, 1973; Shontz, Trumm and Williams, 1971). Color coding works better when the number of objects per category/code is reasonably small (Shontz, Trumm and Williams, 1971; Smith and Thomas, 1964). It has also been shown that color codes are more facilitative when the target code is well known in advance (Green and Anderson, 1956; Smith, 1962; Brooks, 1965; Barker and Krebs, 1977). When the subject already has a strategy for dealing with a code already in use, adding color causes interference with the strategy and can harm performance (Kanarick and Peterson, 1971). Color coding can be superior even to subscripts or underlining in comparison and counting tasks (Smith, Farquhr, and Thomas, 1965). Practice with a particular color code is very effective (Christ and Corso, 1975).

Processing Time

One significant finding is that color-coded instructional materials require a greater amount of time to process and work through than do parallel black/white materials (Lamberski, 1980). Psychologically, color requires more time to perceive (perhaps up to 4 times as long), process, and store (Dwyer, 1972; Berry, 1974; Lamberski, 1980; Gulliford, 1978). When instructional efficiency is defined as achievement gain per instructional time, color and black/white materials produce similar efficiency values (Lamberski and Meyers, 1980). Other studies confirm that because of this increased demand for processing unless this demand is met color may be detrimental or insignificant on learning (Hock and Egath, 1970; Dwyer, 1972; Young, 1973; Berry, 1974; Galbraith, Homann, and Cruetzfield, 1975).

Using Specific Colors

An important question arises about which colors are the most adequate for use in coding. Color imagery is more quickly recognized than black/white; this difference is magnified as resolution decreases (Markoff, 1972). Several studies have examined which colors are most quickly identified. In Table 3-3 the colors are listed in terms of increasing response speed from top to bottom.

Table 3-3
ORDERED RESPONSE TIMES TO DIFFERENT COLORS, FROM
LEAST (TOP) TO GREATEST TIME (BOTTOM)

<u>LEE (1969)</u>	<u>MEISTER AND ULLIVAN (1969)</u>	<u>KREBS, WOLF AND SANDVIG (1978)</u>	<u>BLOOMFIELD (1979)</u>
Red	Red	Red	Red
Blue	White	Yellow	Blue
Yellow	Yellow	Magenta	Green
Green	Green	White	Tan
Black	Blue	Blue	White
White		Green	
	<u>HILGENDORF (1971)</u>	<u>SMITH (1963)</u>	
	Amber	White	
	Violet	Orange	
	Red	Red	
		Green	
		Blue	

Reynolds, White and Hilgendorf (1972) identified the following colors as being associated with fewest identification errors: GREEN, RED, WHITE, YELLOW.

Cook (1974) recommends using the following colors in a display: PURPLE, GREEN, BLUE, YELLOW, ORANGE, RED. This conclusion is based on his review of the literature. Caution must be taken in using the color blue especially for smaller symbols, lines, alphanumerics. Wald (1967) reports that the fovea of the human eye (that which serves to perceive details), is essentially "blue-blind." Blue is best used for large blocks of color coding rather for alphanumerics and small detailed symbols.

Contrast

Some of the background variables are important considerations. In general, the greater the contrast between the background and the foreground colors the fewer the errors that occur in identification (Barnes, 1970). The optimum symbol-background luminance ratio is 10:1 (Barker and Krebs, 1977). As contrast value increases, the reading time of a color code decreases substantially (McLean, 1965). Barnes (1970) reported that a black background resulted in the best performance while a white background resulted in the worst performance. He also found that white, yellow, or orange colors on a black background resulted in optimum performance when compared with other color combinations.

Height of Symbols

The symbol height of colored coded symbols is important in display design. The use of small colored symbols results in the symbols appearing achromatic or in alternate symbols of similar color being confused (Bishop and Crook, 1961; Mavesing, 1976). Smith (1962) constructed a table (Table 3-4) of recommended symbol heights for symbols to be color-coded according to the type of information being presented:

Table 3-4

RECOMMENDED MINIMUM ALPHANUMERIC
HEIGHT FOR COLORED SYMBOLS

<u>Type of Info</u>	<u>High Luminance</u>	<u>Lo Luminance</u>
critical data, variable position	.007-.011	.011-.017
critical data, fixed position	.005-.011	.008-.017
non-critical data	.003-.011	.003-.011

Ambient Illumination

For many displays the major factor contributing to effectiveness is the ambient illumination. Additional ambient light decreases the symbol to background contrast and colors will tend to saturate or fade. Any luminance below 3 cd/m² will result in users being unable to discriminate colors. A luminance of 30-300 cd/m² will allow for comfortable perception of the display. A high luminance (3000 cd/m²) also makes it hard to see colors. Under conditions of high luminance, red becomes the superior color for coding (Barker and Krebs, 1977). When a fast response is needed under these conditions it is recommended that only 3-4 colors be utilized per display (Semple et al., 1971).

The color of the ambient lighting can have a drastic impact on the color code perceived on the display. Semple et al. (1971) provided a table (3-5) listing some of the ambient lighting effects on display colors:

Table 3-5

AMBIENT LIGHTING EFFECTS ON DISPLAY COLORS

Target Color	Red Light	Blue Light	Green Light	Yellow Light
White	Light Pink	Light Blue	Light Green	Light Yellow
Black	Red Black	Blue Black	Greenish Black	Orange Black
Red	Brilliant	Dark Bluish	Yellowish Red	Bright Red
L. Blue	Red	Red	Greenish Blue	Light Reddish
D. Blue	Red Blue	Bright Blue	Dark Green	Blue
Green	Dark Purple	Brilliant	Blue	Light Reddish
Yellow	Olive Green	Blue	Brilliant	Purple
Brown	Red Orange	Green Blue	Green	Yellow Green
	Brown Red	Light Red	Green Yellow	Brilliant Light
		Brown	Dark Olive	Orange
		Bluish Brown	Brown	Brownish Orange

Sampe et al., 1971.

When the luminance contrast is low, the display is dense, or resolution is poor, the size of the symbols being colored must be increased proportionately (Barker and Krebs, 1977). Color requires an increased symbol size of 50% over black and white symbols to be effective. A reasonable standard is 15 TV scan lines per symbol (as a minimum). A black and white system needs only 10 lines/symbol for 100% accuracy in character recognition (Eriksen, 1957; Shurtleff, 1966).

There can potentially be problems with color comparison. Table 3-6 illustrates a study which examined errors in identification of different colors.

Table 3-6

SHOWN	ERRORS IN IDENTIFICATION CALLED					MISCLASSIFICATION
	RED	ORANGE	YELLOW	GREEN	TOTAL	
RED	X	21	0	0	21	2.9
ORANGE	9	X	10	0	19	2.6
YELLOW	0	6	X	15	21	2.9
Green	0	0	6	X	6	.8
					67	2.3

Connolly, Spanier, and Champion, 1975.

When the display constitutes a peripheral field, then blue and yellow panel lights on a gray background with a low amount of

ambient light produce the best results. A white background for the peripheral field caused more errors. When the ambient light was reduced then colors were recognized from further away (Dudek and Colton, 1970).

Number of Colors to Use

The number of colors to use in color-coding display is a critical consideration. Under ideal conditions and with much practice a person can identify up to 50 colors (Hanes and Rhoades, 1959). However, good accuracy of identification can be obtained under ordinary circumstances with 10 colors (Barker and Krebs, 1977; Conover, 1959). Shontz, Trumm and Williams (1971) recommend that a maximum of 23 colors can be used for color-coding in search tasks. It must be remembered that as the number of colors used as codes increases, so do errors. Table 3-7 shows how errors increase with number of colors:

Table 3-7

INCREASING COLORS AND RESULTING ERRORS

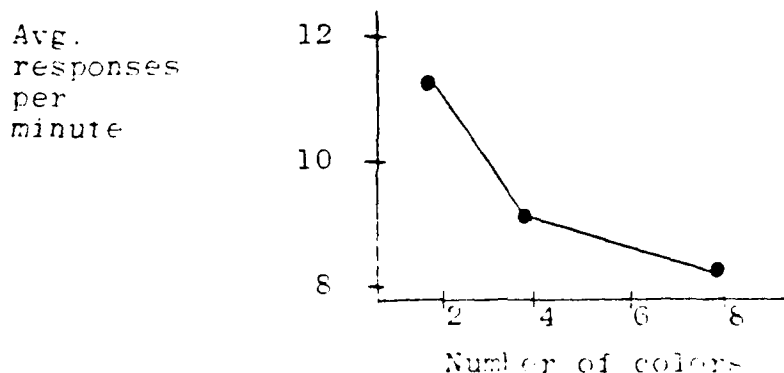
<u>No. of colors</u>	<u>errors (%)</u>
10	2.5
12	4.5
15	5.2
17	28.6

Four colors (RED, ORANGE, YELLOW, and GREEN) can be identified with 97-99% accuracy (Connelly, Spanier, and Champion, 1974).

On the other hand, as the number of colors used as codes increase, the response time/search time decreases. The following graph, Figure 3-1 from Hitt (1961) shows the relationship:

Figure 3-1

Effect of number of code levels on performance



Redundant Color Coding

or print channels (Mowbray, 1952, 1953, 1954; Klemmer 1956, 1958; Bulgarella and Archer, 1962; Lockhard and Sidowski, 1961; Williams and Derks, 1963; Koen, 1969). Visual modes are more facilitative for complex tasks (Gulliford, 1973). A third caution relates to the amount of time a learner is allowed to interact with multiple coded materials. When using two channels it is imperative that the learner have sufficient time to process the dually coded information. If the presentation rate violates these, the learner's performance will degenerate (Gulliford, 1973).

The following are some specific findings about the use of color as a redundant code:

1. When partially redundant color is added to a search display and the subject does not know the color, the search performance deteriorates. The search time increases by 23% over a monochromatic display and 72% over a color coded display. (Christ, 1975)
2. Redundant color coding in symbolic displays does not decrease search time when the subject knows the target color before hand. (Christ, 1975)
3. The advantage of knowing the target color in advance increases as the density of the symbols increase and as the number of non-target colors increases. (Christ, 1975)
4. Without a redundant color, when the display density increases and/or the number of non-target colors increase, search time accordingly increases substantially.
5. For partially redundant color-coding which the subject knows in advance, the search time decreases, but as the number of non-targets bearing that same color increases, searchtime begins to increase until the number of non-targets exceed 70% of the total number of targets at which point knowing the target color is a disadvantage. (Christ, 1975)
6. When the subject knows the target color beforehand, the decrease in search time and gain in overall performance remains whether the color is used redundantly or not. (Christ, 1975; Sanez and Richie, 1974)
7. Using code redundantly leads to an increase in accuracy in the identification of simple targets (it has a 6% advantage over size code, 104% over brightness code, 61% over size and brightness code). (Christ, 1975)

8. The maximum amount of information transmission occurred for all amounts of transmitted information when a color code was used redundantly with a numeric code. It surpassed the numeric alone as well as the color code above. (Anderson and Fitts, 1958)

An important point to bear in mind in considering redundant coding is the increase in complexity and number of stimuli being presented. Any increase in display complexity and density results in greater errors and search time (Green and Anderson, 1956; Smith and Thomas, 1964; Smith, 1963). Thus, codes have to compensate for these efforts and facilitate. Multiple codes used non-redundantly can help increase the number of symbols which can be absolutely identified on a display (Barker and Krebs, 1971; Garner and Creelman, 1964; Ericksen, 1954). It also helps to increase the number of identifiable categories of information (Barker and Krebs, 1977). Partially redundant codes can be used when information can be categorized at more than one level of specificity. Totally redundant coding should be used when targets or stimuli can be identified on several dimensions. This improves symbol detectability, the probability of being identified, and discriminability among symbols.

SECTION III MOTION

III.1 GUIDELINES

- Complex, fixed pace, motion graphics may be beneficial for individuals of high mental ability but may deter learning for individuals of lower mental ability. (Merrill and Bunderson, 1979)
- Motion generally has little effect on learning except when the information to be learned deals directly with motion or change. However, we hypothesize that realistic dramatic sequences may have considerable value in increasing interest, motivation, emotional impact, and in changing attitudes. (Merrill and Bunderson, 1979)

III.2 SUPPORTING RESEARCH ON MOTION

The research shows that motion generally has no effect on learning unless the task to be learned uses motion (Levie and Dickie, 1973; Silverman, 1958; Allan and Weintraub, 1968). For tasks involving motion, motion pictures are better than sequential still frames. Slides are even better than the sequential stills (Wells, Van Mondfrans, Postlethwait, and Butler, 1973). For teaching concepts involving time, movies are superior (Gulliford, 1973). When the learning tasks involve factual recall, motion as well as dramatization, music, and realism do not facilitate achievement (Hoban and Van Ormer, 1950; Travers, 1967). Repeating motions of motor skills improves acquisition (Hoban and Van Ormer, 1950).

A problem with motion pictures is that real time may go so rapidly that the learner is unable to perceive and process well (Merrill and Bunderson, 1979). Also, research on motion films has shown that even when the topic has inherent motion only about 45% of the motion is relevant. For other topics where motion is not crucial it is estimated that 90-95% of the motion could be eliminated without reducing comprehension (Gulliford, 1973).

Allen, Daehling, Russell, and Nielsen (1970) compared motion pictures, still frames, print, and audio. They showed that motion is very effective, but if they added audio to the motion the advantage of motion over stills was eliminated. Audio with still pictures worked as well as audio with motion. Similarly, other researchers have identified instances where motion pictures are equal to still frames (Allen, 1960; Allen, Cooney, and Weintraub, 1968; Wells, et al., 1973).

A study conducted by Wells et al., (1973) looked specifically at the differences between presentation of concepts involving either time or space using still photographs, slide/tape, and movies. Their results indicated that for concepts involving time (i.e., a series of continuous events), movies were better than the static presentations. However, the opposite was true for concepts involving space. This suggests that motion may be important for certain types of procedural instruction.

Animated Three-Dimensional Graphics

Research has shown that animated three dimensional graphics can aid in maintenance and performance tasks with real objects (Bocher, 1978; Brock, 1978; Crawford, 1977; Frey and Eikert, 1978).

Merrill and Bunderson (1978) suggest several areas where motion instruction could be beneficial. These major areas are presented in the following sections.

Performing Gross Motor Skills

Motor behavior occurs when a trainee is able to execute a physical movement with precision and appropriate timing. Motor skills are involved in such Army tasks as: marching, swimming, painting a barracks, typing a report, operating a piece of equipment, using hand tools, adjusting a microscope, etc. Motor behavior often involves the execution of a series of several coordinated movements. The order in which these individual movements are performed may be taught independently from the actual movement. For example, the order in which the parts of a rifle are assembled may be taught independently from the motor skills required to put the parts together. The role of graphics in teaching procedures is described in another section.

It is difficult to imagine a trainee being able to learn a complex motor skill solely from verbal or textual information.

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The movements must be demonstrated to the student: either by an instructor or through the use of some pictorial representation. In some situations, a live demonstration may not be ideal if the model is unable to perform the movement slowly enough for the trainee to see the critical aspects of the movement. The serving of a tennis ball is difficult to demonstrate for this reason. A series of still pictures which show critical positions or aspects of the movement in discrete intervals across time may be more instructive. Frazier (1978) refers to this as pseudo-animation. If care is not used with pseudo-animation, the critical continuity of the movement may be lost. A motion picture has some of the same advantages and disadvantages of a live demonstration. If the movement is shown in real time, it may be too fast. However, slow motion would demonstrate the continuity of the movement while slowing it down so that the critical aspects could be perceived. Repetitions of the demonstration or motion pictures can improve the learning of motor skills (Hoban and Van Orman, 1950). Learning may also be facilitated if the trainee can stop the motion picture film and practice the motor skill rather than trying to practice the skill while the film is in progress. Even mental practice, where the learner thinks through the various motions may be effective (Travers, 1967, Bandura, 1977). The videodisc may make a significant contribution in this learning area as it has better capabilities for slow motion and freeze frame than videotape and film.

Practice is crucial in the learning of a motor skill. However, practice is only beneficial if the learner receives some feedback. This feedback may be intrinsic to the task (as when the correct letter is typed on a piece of paper), or may require the judgment of an instructor. Many complex motor skills are difficult to learn because trainees cannot totally observe their own responses and thus are unable to compare their responses with the correct form (Bandura, 1977).

This problem can be alleviated by videotaping the trainee's performance and using the videotape for feedback.

Steering and Guiding-Continuous Movement

Steering and guiding behavior involves a perceptual-motor skill where the trainee must continuously scan or monitor certain external cues and execute appropriate movements on a continuous basis in accordance with the perceived cues. Such skilled behavior is required in driving a tank down a road, landing an aircraft, tracking an air-to-air gunnery target, etc.

Steering and guiding behavior involves a combination of the skills where relevant cues are embedded in a high noise environment. Cues then serve as signals for the execution of the appropriate motor skills.

In the early stages of training, the detecting of relevant cues should be taught independently of the motor skills, using graphics as described by Merrill and Bunderson (1978). The motor skills could be taught as described in the section on "Motor Skills." The intermediate stages of training should integrate the detecting of cues with the corresponding motor skills. The integration of these skills could take place in a training simulator such as the Link Trainer.

In the final training stages, the learner should be given opportunities to practice and demonstrate proficiency in a realistic setting. Practice and corrective feedback are absolutely essential.

Complex Procedures

Many procedures are so complex and/or the consequences of error are so great that it is impractical to require trainees to memorize the sequence of steps. In such cases, a job aid which lists the steps or presents a flow chart of the steps should be used.

If the procedure involves extensive motor skills, the steps of the procedure and the motor skills could be taught simultaneously by live demonstration, motion pictures, (with slow motion if real time is too fast), or with a series of still pictures (see section on Motor Skills). If film or pictures are used to demonstrate the steps of the procedure, the performance should be photographed so that the representation shown has the same view or angle that the trainee would see if he were doing the procedure himself (Hoban and Van Ormer, 1950). The videodisc allows for a combination of slow motion and still graphics that was difficult, if not impossible, with previous technology.

If the procedure involves the assembly of a piece of equipment with many parts, and the motor skills required already exist in the repertoire of the learner, graphics would not be necessary to show the actual motor skills required. However, graphics would be necessary to show the various parts of the equipment and their relationship to each other. The graphics would need to be supplemented with verbal or textual instructions which list the order in which the various parts should be assembled.

Whenever feasible, the trainee should be given opportunities to practice performing the procedure using equipment. In any case, hands on performance testing should be included to insure learning transfer has occurred.

This concludes the Merrill and Bunderson summary, 1978.

Cartoons

Cartoons have been the subject of some experimental scrutiny. Kaufman and Dwyer (1974) showed that cartoons were preferred

over photographs and that they were more effective on both immediate and delayed recall. Other studies have shown that instructional cartoons are no more effective than other presentation techniques, but may promote a more favorable affective response (Baker and Popham, 1965; Popham, 1969; Freisinger, 1976; Lumsdaine and Gladstone, 1958). One study reported that cartoons require a significantly shorter time to perceive and process than line drawings, photographs, and shaded drawings (Ryan and Schwartz, 1956).

In a recent study, Sewell and Moore (1980) help to clarify these ambiguous findings. They conclude that if the dominant concern is for students to enjoy the topic then cartoons are the most effective type of visual. However, if the objective is comprehension then cartoons are not worth the cost needed to develop because printed text is equally effective and cheaper to produce.

Animation

It is difficult to find research that examines the instructional effect of animation. It seems to be primarily prized for its entertainment value and only secondarily for its instructional potential. In recent instructional development efforts, especially since the advent of CAI, animation has begun to be taken more seriously as an instructional medium. Current advances in computer technology are starting to pave the way for innovative ways of using graphics in instruction never before available. Two notable innovations that will be discussed here are computer-generated imagery and animation.

Because this development is so new little experimentation has been done to compare its relative effectiveness. Some dramatic anecdotal evidence recently reported in an editorial (Lodding and Nickson, 1980) might foreshadow the future of computer-generated animation. A group of researchers concerned with the workings of an internal combustion engine developed an animated simulation. During the initial previewing of the film the researchers noted an unanticipated erratic phenomenon. It turned out that this was an acoustical oscillation of fuel within the cylinder which had been happening all along but had never been noticed. Earlier numerical simulations had hidden this because of the phenomenon's relative obscurity amid other dominating happenings. This discovery turned out to be very significant because the phenomenon had direct bearing on the engine's fuel efficiency. The important point is that such a critical phenomenon was totally concealed until brought to light through sophisticated computer capabilities.

The salient concern of researchers is how to improve the technique and quality of this computer-generated art. Instead of worrying at this point about human performance effects, it is worth noting the extent to which computers are being utilized in the production of various kinds of visual aids. The following is a sampling of the variety of ways they are used:

1. Animation--cartoons, special effect movies, TV commercials (Borrell, 1980).
2. Simulation--flight-training (Borrell, 1980).
3. Computer-generated imagery--logos, 3D figures, slide designs (Nouri, 1980; Lewell, 1980).
4. Computer-aided design--architecture, printed-integrated circuitry (Borrell, 1980).
5. Computer-assisted cartography--geographical information system (Borrell, 1980).
6. Information systems graphics--home information systems, management information systems (Borrell, 1980).
7. Computer-assisted instruction.
8. Medicine (Borrell, 1980).

It is evident that computer assistance in the production of graphics has already pervaded many disciplines. It is just becoming a widely used device for visual communication.

There are two methods utilized in this computer-assisted graphics. The most prevalent is the digital method. The artist inputs a drawing directly into the computer by way of a digitizing tablet. The entire picture is broken up into minute points, termed pixels. The artist has direct control over each pixel and, then, can manipulate the original drawing in many ways. The artist can store, change color, adjust position, modify size, or add depth to the image or any part of it (Lewell, 1980). The artist has a wide range of power to manipulate the image as he sees fit. He can tear it apart and recombine bits and pieces to make an entirely new image (Trost, 1980).

All of these artistic manipulations are quite simple. The artist can choose any of 256 colors and by merely touching it with a stylus he can experiment with different colorings. He can experiment with hue, saturation, brightness and grey scale (SMPTE, 1980). In addition, the computer can generate certain geometric shapes (e.g., circles, squares) for use in his art. He can also store specialized shapes and characters for later use (SMPTE, 1980).

The significance of the digital method is the tremendous control and flexibility the artist has. For the average color TV monitor, he has direct control over 250,000 pixels in a number of different ways. The resulting creation can be output to either video or film (Nouri, 1980). The artist has never been so free to experiment with his work.

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The second method is the analog computer system. A black and white drawing is transmitted to the computer by way of a video camera. Once in the computer the picture can be manipulated. With this method the video signal is under the control of the analog computer and an artist can create flips, bends, and oscillations to make a very sophisticated image (Nouri, 1980). There is not the extensive control over the image in the analog as with a digital. Moreover, the analog method is much quicker (Trost, 1980). Eventually the artist who wants ultimate control will have to digitize the original image.

The CAESAR (Computer Animated Episodes using Single Axis Rotation) system combines both the analog and digital. The initial input picture is broken down into segments of the picture such as a leg or arm. The control isn't over individual pixels but over these larger components. These components can be rotated or changed as desired. Other components can be added to the scene to create the desired effect. Animation is produced by drawing the final frame of a sequence and then directing the computer to produce all the in-between sections from the initial to the final by averaging out the changes across the number of frames.

There have been several criticisms made of computer-generated imagery and animation. First, because the computer averages out motion across frames there is a loss of the "imagination" and "sympathetic naturalization" that an artist lends to his work (Nouri, 1980). Second, there is generally a poor or inadequate resolution of figures, although this state of affairs is improving rapidly (Nouri, 1980). Third, the speed of digital computer production is rather slow. It takes time to produce art this way (Lindner, 1980). Fourth, real time animation remains problematic. There are 250,000 to 1,000,000 pixels required for each frame and at 30 frames per second achieving real time animation is a very difficult task (Lindner, 1980). Fifth, although the prohibitive costs of the past have been substantially reduced, the cost of computer production remains high (Lindner, 1980). These are genuine limitations which prohibit more expansive use of computers in design. However, efforts are being made to overcome them and many of these will be solved in the very near future.

The advantages of using computers to generate graphics have been extensively identified in the literature. First, tedious aspects of artistic creation (e.g., opaquing and inking) are done by the computer (Nouri, 1980). Second, the editing powers by way of the computer control are enormous. The capability of changing, at will, colors, hues, speed, motions, and positioning, allows the artist to see and tinker with a picture immediately. Editing takes only a few seconds and no redrawing or reshooting is required (Nouri, 1980; Borrell, 1980; Lindner, 1980; Asaniraye and Futai, 1980; Trost, 1980). Third, the notion of computer animation is more fluid (Lindner, 1980; Trost, 1980). This

can be due to the increased frame rate of the computer animation (30 per second) over film (24 per second). Fourth, computers allow the artist of more colors than film (Lindner, 1980). Fifth, color shift does not occur nor do oil layers (Lindner, 1980). Sixth, there is no deterioration of color or picture over time and usage (Asamizuya and Futai, 1980). Seventh, output of drawings can be rapid (Borrell, 1980). Eighth, the storage of the work is far more convenient (Borrell, 1980).

The future of computer graphics looks very bright. Writings are replete with predictions. Perhaps the most significant forecast is that soon computer-generated animation and imagery will exhibit a greater realism than even film is capable of (Lindner, 1980; Nouri, 1980; Prince, 1980; Brown and Levine, 1980). The price of graphics systems as well as memory will decline (Brown and Levine, 1980; Lindner, 1980). At the same time there will be better graphics software which will enable even more control over editing the image (Lindner, 1980). There will be better resolution, better video displays, better input devices, hardware that will enable excellent reproduction of computer generated images and more available memory (Brown and Levine, 1980).

The artistic capabilities will be multiplied. Brown and Levine (1980) make a very interesting prediction:

"True three-dimensional displays will become common. Researchers will finally be able to see their models in three dimensions without the need of special glasses, stereo pairs, or by viewing the two-dimensional projections."

They optimistically predict that computers will revolutionize the art world in the same way that acrylics did.

SECTION IV. SOUND AND VOICE INPUT AND OUTPUT

Research on Use of Sound

Sound is an important determinant of the effectiveness of instructional materials. As reported earlier, redundant sound with visuals increases comprehension (McCormick, 1970; Buckner and McGrath, 1961; Synrons, 1963; Speith, Curtis and Webster, 1954; Mudd, 1961; Day and Beach, 1950; Huban and Van Ormer, 1950a; Hartman, 1961a; Miller, 1956; Pollack and Ficks, 1956). Dwyer (1978) lists 56 studies which support this claim. In an extended series of studies at Johns Hopkins, Chapanis (1973, 1975, 1976a, 1976b) and his colleagues (Chapanis, Ochsman, Parrish and Weeks, 1972, 1977; Chapanis and Overbey, 1974) have investigated two person problem solving dialogues intended to simulate man-computer interactions of the future. They have consistently found that oral communication (voice and natural communication) results in much faster problem solving than typing or handwriting. As might be expected, the number of words and messages is far greater with voice than with written communication. They also found, however, that natural human communication is characterized by many small errors, which would quickly confuse current computer systems.

Experiment 5 of the research conducted for the Presentation Features project found a similar result. Subjects using voice input would mumble to themselves, give tentative answers, and in other ways violate the very structural input rules normally associated with a keyboard. It is clear from both Chapanis' work and our own that while voice input and output is potentially a very efficient means of communication, the computer will have to develop a framework of expectations so that it knows what it is looking for in the conversation. Humans appear to do this all the time. Moreover, human conversation is particularly forgiving of errors in syntax and even in thoughts. Again, this is probably because each partner has an understanding of the subject matter and a set of expectations for what is likely to come next. In computer science these matters are commonly referred to as "natural language understanding." Significant progress has been made in this area in the last decade (cf., Brown, Rubinstein, and Burton, 1976), but much remains to be accomplished before a fielded system is available for general purpose interactions. In the meantime, voice and other sound output will be used far more than voice input, which will primarily be used where hands or eyes are busy, or the user is away from a terminal. Chapter 6 presents voice input systems in more detail.

Sound Presentations

Realistic voice or other sounds are required for many kinds of modeling, where the objective is to change attitudes or to illustrate a procedure by presenting an expert. Moreover, sounds are required to make certain discriminations (e.g., between a

motor running smoothly or roughly) These uses are especially important for simulations where the student needs realistic presentations in order to gain hands on experience.

We hypothesize from observation that non-voice sounds (e.g., those in penny arcade games) can add excitement and motivation to simulations, and that such simulations and games may increase the number of hours of practice that students will put in. This observation has been repeated with many different content areas and ages of students.

Presentations Using Sound

Sound is widely used for training and simulation applications. These include voice output, music, and tones (e.g., as used in electronic games). Analog systems, for example as found in the videodisc, permit all three of these types to be recorded and presented. Digital recording is also available, and, if sufficiently high quality, can present both music and voice. An alternative to digital recording is to synthesize either tones or a voice using hardware. In general, analog recordings have the highest fidelity, digital recording comes next in quality, and synthesized sound has the lowest quality. However, digital recording can be arbitrarily good, and can easily exceed the capabilities of even the best analog recordings. On the other hand, the storage requirements for very high fidelity digital recordings are severe. One application of high fidelity digital recording is to present symphonies on a small optical videodisc which has a very large memory capacity.

As described above, voice quality varies widely depending upon the type of system used. Not surprisingly, the quality required determines to a large extent the price for a system.

Recorded Sound. A number of means are available to record voice. One of the most simple is pulse-code modulation (PCM). This is a simple digitization of the voice input. It is very flexible, easy to use, offers arbitrarily good fidelity, and uses a great deal of memory. Another approach to voice recording is delta modulation. This approach offers many of the same advantages as pulse code modulation, but also includes the disadvantages of high storage requirement.

A quite different approach is to model the human vocal tract and to store only the data from the incoming voice signal which is required to drive the vocal tract model to reproduce approximately the same sound as was input into the system. Whereas PCM and Delta modulation permit both voice and music to be recorded, LPC is limited to voice, since it uses a model of the vocal tract. LPC uses far less storage for equivalent quality than either PCM or Delta modulation. Thus the delivery side of LPC can be very inexpensive. For this reason LPC is the method used by Texas Instruments in their talking games. The drawback is that encoding

the voice input is quite complex and expensive. Where this cost can be amortized over thousands of delivery systems, the problem is less severe than in a development shop which is constantly trying new sounds.

Synthesized Sound. An alternative to recorded voice is to synthesize the voice output from speech sounds like phonemes and allophones (parts of word sounds). This approach is by far the least expensive and most flexible for change (since new words can be created by simply typing in the string of speech sounds). On the other hand, this approach produces robot-like sound which is far below the quality of recorded voice at present.

SECTION V. INTERACTION PROCESSES

Types of Interactive Dialogues

An excellent resource for interactions and other basic features of man/machine design is Human Factors In Computer Systems: A Review of the Literature by H. Rudy Ramsey et al (1979). Table 3-7 presents their typology of interactive dialogues.

The bulk of electronic delivery system interactions for instruction consist of a simple prompt or question and a student response. These interactions are reminiscent of a programmed text or workbook approach. The nature of interactions can be significantly changed if an electronic delivery system is used for simulations and activities which require the student not only to learn about the content but rather to actually engage it and take part in it. An example is a two dimensional (TV screen) simulation in which a student must troubleshoot an electronic circuit. Here the student initiates the bulk of the interactions and uses the electronic delivery system as a tool or a resource for gathering information about the system.

Components of Interaction

This level of interactions requiring preformatted displays, responses to the display, and branching to other preformatted displays does not require much processing intelligence on the part of the delivery system. Machine (or artificial) intelligence permits more sophisticated levels of interaction. An intelligent system of interactions consists of four elements:

- (1) An interactive model of the content being taught. An example is the piece of equipment being simulated in a maintenance troubleshooting task or the set of rules of arithmetic which are used by a student who is practicing subtraction.
- (2) A model of an expert who operates the system. An example of this is a troubleshooting procedure or an algorithm for doing long division. The expert function can be very simple or very complex. A simple function is a list of steps in a procedure. A more complex expert would be a chess playing program.

Dialogue Type	Description	Comments	Principal References
Question and Answer	Computer asks a series of questions, to which user responds.	Inherently computer-initiated. For totally naive user, this is probably the most error free dialogue type. This approach rapidly becomes cumbersome as the user gains experience.	Card et al (1974) ¹⁰⁰ Lucas (1977) ¹⁰¹
Form Filling	Computer presents form with blanks. User fills in blanks.	Computer-initiated. Faster than ordinary question-and-answer dialogue, because user provides several responses in a single transaction. When user input is dominated by parameter values, rather than commands, this approach is often best. Other than casual use requires terminal with tabbing feature. Under some circumstances, a significant proportion of syntactic data entry errors may be detected if terminal has provision for imposing constraints on data by field.	Martin (1973) Pew & Hollings (1975) Stroh (1975) ¹⁰²
Menu Selection	Computer presents list of alternatives, and user selects one or more.	Inherently computer-initiated. Can be used for command construction as well as data base search. Very natural dialogue if response time criteria are satisfied and "point in" selection device (e.g., light pen, touch panel) is used.	Martin (1971) Balsdale (1976) ¹⁰³ Ding-Yun (1969, 1973) Hoff et al (1974)
Function Keys with Command Language	User indicates desired action by depressing keys, each of which represents a command, command modifier, or parameter value.	User initiated, but with keyboard as memory aid. Can be computer-initiated if "programmable" keyboard or tutorial displays are used. Often appropriate when user input is dominated by commands, rather than parameter values. Appropriate for naive user only if command syntax is very simple and/or computer-initiated form is used. Otherwise requires training. Constant presence of all commands and modifiers may make it difficult for user to learn appropriate model (e.g., hierarchical structure) of command language. If language is not simple.	Martin (1973)
User Initiated Command Language	User types commands, perhaps using mnemonic abbreviations.	Acceptable approach for well-trained user who has fully internalized model of system function and language syntax. Otherwise error prone and sometimes frustrating. Usually preferred by system designers and programmers, who tend to satisfy these criteria. Often applied uncritically by them to systems in which user does not satisfy criteria.	
Query Language	User inputs questions or data base access procedures to a data base system. System produces response or report.	Several existing query languages appear to be useable by both novices and programmers, but many errors occur in their use. The problem areas appear to be reasonably well known, but only fairly general solutions can be confidently prescribed. Detailed guidelines for query language design would be premature.	Gould & Ascher (1975) ¹⁰⁴ Reisner (1977) ¹⁰⁵ Thomas (1976) ¹⁰⁶ Thomas & Gould (1975) ¹⁰⁷
Natural Language	Dialogue is conducted in user's natural language (e.g., English).	Can be user- or computer-initiated or mixed initiation. Fairly high powered natural language capabilities are now achievable. Cost is very high, however, since the system requires an extensive "knowledge" of the application area in order to understand user inputs. Development of such a data base is definitely a nontrivial task, and is not for unsophisticated designers. "Natural" language may not be the most "natural" dialogue type for many applications (e.g., engineering drawing, mathematics).	
Interactive Graphics	Generation of pictorial displays, ability of user to select displayed entities and spatial locations by pointing or similar nonverbal means.	This is not truly a dialogue type, but interactive graphics offers great additional dialogue flexibility. With rapid response (as by use of smart terminal with refreshed graphical CRT display), very rapid, flexible and "natural" dialogues are possible. Interactive graphics is relatively expensive, but costs are dropping. Performance improvements may offset extra cost even in some relatively mundane applications (e.g., search of hierarchical data base). Most research on interactive graphics is concerned with details of input and output devices and techniques, rather than overall dialogue properties. See later sections on these topics.	Foley & Wallace (1974) Martin (1973)

Figure 3-7. Basic Interactive Dialogue Types.
From Ramsey et al. 1979.

- (3) A model of each student. The model can be very simple, for example the number of right and wrong responses on a series of mathematics problems. Or the model can be quite rich, and include an estimation of the student's skill in each of 30 areas required to fly a jet plane. The major point to be made about the student model is that it is not simply a record of the student's key presses or other interactions with the system. In order to model the student in any useful way, the student's interactions must be related to the content. An example is a drill and practice program in reading which aids the student to master letter-sound correspondences. The student's successes on each spelling pattern can be recorded independently. In this way the interactions are related to the content structure.
- (4) An advisor to make comments or sequence activities that will move the student performance closer to that of the expert. In essence, the advisor must compare the student's performance to expert performance, then determine which skill area will be worked on next and what method will be used to decrease the difference between the student's performance and that of the expert. The advisor function may be handed over to the student who must then decide what to study next. This may have the advantage of providing a "learning to learn" phenomenon whereby the student improves in the skill of selecting what to study next and how to study it. On the other hand, it can readily be shown in paired associate tasks that a powerful learning model can estimate the student's state of knowledge better than the student can. In this case, a computer advisor may be able to optimize the learning process.

In a classroom, the subject matter is the content model. The text or technical manual holds the expert model. The instructor serves both an expert and advisor role, while the grade book contains the student model. The video materials and computer program of an electronic delivery system can serve all of these functions. What the electronic delivery system adds is the capability to replicate the work of an excellent instructor and set of course materials.

Without the capability of replicating excellent interactions, the effect of a good instructor is quickly lost when the instructor leaves. We are all familiar with remarkably innovative, productive, and exciting interactions and programs which revolve around a small group of people and are quickly lost when the group disbands. The electronic delivery system is a means of being personal with every student. Unlike a videotape presentation, the electronic delivery system can and should replicate the interactions of an excellent instructor with a student.

Interaction Modes

The four aspects of fully intelligent interactions may be operating simultaneously and invisibly while the visible interactions occur. Visible interactions on electronic delivery system may be classified in three modes: presentations, exercises, and generative interactions.

In presentation mode material is presented to the student who is essentially a passive recipient. Non-interactive pages of text or motion segments are presented with accompanying audio or illustrations in any combination. The user can control the rate and sometimes the sequence of the presentation. In essence, however, this mode is simply passive viewing or page turning. It may present an expert procedure, but does not permit interaction with the model of the content, or with an advisor. It also keeps no model of the student.

The exercise mode permits users to respond to stored questions or problems, and to receive immediate feedback. Branching depends upon the responses of the student. Thus the exercise mode may use the expert, student model, and advisor functions. Without two screens or without text and graphics overlay, most videodisc systems stop with this mode. It should be noted that some simulations for fixed sequence procedures use this mode since they are simply a linear sequence of actions to be performed. The student may be prompted and then take a particular action. This corresponds to a standard multiple choice problem in which a prompt or question is posed and the student is to give one of several responses.

The generative simulation mode introduces a model of the system, which permits new items to be generated. The generation procedure can be as simple as producing new arithmetic problems or as complex as modeling a navigation system for an aircraft. The generative simulation mode provides realistic exercise of concepts and rules while maintaining test integrity, since new items can be generated using the same rules for test items as for practice items. This mode permits user interactions to be more extensive, since new exercises can be produced to fit individual needs. The expert, student model, and advisor functions may also be included.

Experiment 2 of this Presentation Features study compared a job aid type of interaction with instruction. We found no significant differences in total time or accuracy on a performance task under these two interaction conditions, so long as total time was compared (learning plus performance on the one hand vs. performance with a job aid on the other). Appendix A presents this experiment in detail.

CHAPTER 4

HUMAN FACTORS FOR VISUAL DISPLAYS

Visual displays have certain parameters or factors that affect how well an image can be seen and, if the image is a written message, how well it can be read and understood. In the section below we will delineate several human factors that affect the visibility and legibility of visual displays. Some of the factors apply most directly to CRT displays and, since CRT's are the most common display form for general purposes, emphasis will be given to CRT applications. It should be noted, however, that most of the factors discussed below are relevant to other kinds of displays. Other displays are discussed under Output Devices.

Visibility

Visibility factors range from classical display factors such as luminance, contrast, and resolution to display problems such as flicker, blur, and glare. Each of these factors will be briefly defined and described. Recommendations or specifications made in the literature will be noted. Table 4-1 is a summary of visibility parameters whose structure follows the outline of the text. We have included recommendations from four basic references --Shurtleff (1980), Bean (1980), Cakir, Hart & Stewart (1980), and Sherr (1979)--as part of the table to indicate how much agreement there is between researchers regarding design specifications and recommendations for the factors.

Luminance

Although luminance is fairly simple concept intuitively, it is surprising how complex the technical definition actually is. Sherr (1979) defines luminance as:

"The measure of luminous intensity of a light emitting or reflecting surface in a given direction, per unit of projected area of that surface as viewed from that direction." (p. 3)

More simply put, luminance can be thought of as intensity of light emitted from a given point or, in short, photometric brightness. Luminance is expressed either in foot-Lamberts (fl) or in the metric unit, the nit, or candela per square meter (cd/m^2). A multiplier of 3.4 is used to convert from foot-Lamberts to nits.

A visual display must reach a certain level of luminance to ensure visibility (Gould, 1968). Shurtleff (1980) specifies 10-50 fl (34-171 nits) as a minimum range of luminance for characters on a CRT screen. Bean (1980) considers 10-100 fl (34-343 nits) to be an acceptable range for the screen background. Cakir, et al. (1980) set 45 nits as the minimum character luminance and 80-160 nits as the preferred range.

Table 4-1 continued

FACTOR OF INTEREST	INTERACTING FACTORS	SHUTTLEFF (1980)	HEAN (1980)	CAYLOR, HART, and STEWART (1986)	SHERR (1979)	COMMENTS
<ul style="list-style-type: none"> Gray scale (dynamic range) number of levels or steps of brightness perceived by the viewer (contrast, luminance ratio of gray as a function of the level of luminance) 	<ul style="list-style-type: none"> luminance, contrast 	(NO RECOMMENDATIONS)	(NO RECOMMENDATIONS)	<ul style="list-style-type: none"> number of levels in gray scale should suit the task; for most graphics, gray scale should be more than 3. 	<ul style="list-style-type: none"> more than 4 levels are not readily justified for most purposes, allow about 2 "bands" (see definition) for each coding level 	<p>Graphics displays require greater dynamic range than alphanumeric displays. Since the average person can only detect about 4 levels of gray scale on a CRT, greater contrast abilities are not needed.</p>
<ul style="list-style-type: none"> Refresh rate (frames per second) 	<ul style="list-style-type: none"> refresh rate, phenomenon, display size, character density 	(NO RECOMMENDATIONS)	(NO RECOMMENDATIONS)	<ul style="list-style-type: none"> 50-60Hz (optimum) 	<ul style="list-style-type: none"> 50Hz refresh rate minimum 	<p>50-60Hz refresh rate should avoid flicker. Since U.S. TVs are 60 Hz, flicker should not be a major problem.</p>
<ul style="list-style-type: none"> Stability (jitter, drift, irregularities in the power supply) 	<ul style="list-style-type: none"> luminance 	(NO RECOMMENDATIONS)	(NO RECOMMENDATIONS)	<ul style="list-style-type: none"> display should be free from jitter and drift 	(NO RECOMMENDATIONS)	<p>Irregularities in the power supply can cause image instability, which is probably more common than flicker. No easy solutions; try to stabilize the power supply.</p>

Table 4-1 continued

FACTOR OF INTEREST	INTERACTING FACTORS	SHUTTLIFT (1980)	HEAN (1980)	CARLIS, HART, and STUMWANT (1980)	SHERR (1979)	COMMENTS
<ul style="list-style-type: none"> Direction of contrast of characters on dark background or dark characters on light background. 	<ul style="list-style-type: none"> Background lighting 	<ul style="list-style-type: none"> not a major factor switching capability may be useful for poor viewing conditions 	<ul style="list-style-type: none"> not a major factor 	(NO RECOMMENDATIONS)	(NO RECOMMENDATIONS)	<p>General agreement that contrast polarity is not a critical factor; the commonly used white on black polarity is acceptable. Effects on operator fatigue are unknown.</p>
<ul style="list-style-type: none"> Character size measured by the diagonal distance. 	<ul style="list-style-type: none"> Resolution, size character 	<ul style="list-style-type: none"> depends on use as: input/output terminal, military console group, or remote viewing procedures for determining viewing area requirements 	(NO RECOMMENDATIONS)	<ul style="list-style-type: none"> 12" or 15" most common Depends on information requirements--the more information to be displayed, the larger the screen. 	<ul style="list-style-type: none"> Larger screens can present more characters. 	<p>Screen size requirements depend on the amount of information that must be displayed on the screen at one time, which is itself a function of display purpose and other variables. 12" to 15" screens are the most common display size; group and remote viewing will require larger display surfaces.</p>

Table 4-1 continued

FACTOR OF INTEREST	INTERFERING FACTORS	SHURTLEFF (1980)	HEAL (1980)	CARP, HART, and STUWART (1980)	SHERR (1979)	COMMENTS
<ul style="list-style-type: none"><u>Viewing angle</u>--the angle between the line of sight and the display. On-line viewing of which the operator views the display. On-line viewing is	<ul style="list-style-type: none">screen size, character spacing, viewing distance, other legibility factors	<ul style="list-style-type: none">system selection criteria based on viewing area off-center with-out decreased performance (Shurtleff, 1980)require site make some allowance for off-center viewing.	<ul style="list-style-type: none">up to 10 degrees off-center with-out decreased performance (Shurtleff, 1980)	<ul style="list-style-type: none">for 30 min arc, 30° is acceptable	<ul style="list-style-type: none">Input/Output terminals require less allowance for viewing angle variation than other purposes requiring remote or group viewing. Shurtleff (1980) establishes value requirements for use in selecting appropriate display hardware.	
<ul style="list-style-type: none"><u>Background luminance</u>--the luminance of the background as the reference point for the luminance of the display. (luminance) or light intensity (lumens per meter squared) of light reflected by the background. It is the amount of light coming from the display screen.	<ul style="list-style-type: none">display type (light-emitting vs. light-controlling), display luminance and contrast, direction of contrast	<ul style="list-style-type: none">(NO RECOMMENDATIONS)	<ul style="list-style-type: none">10-100 fL (luminance)	<ul style="list-style-type: none">300-500 lux or lumens per meter squared (illumination)	<ul style="list-style-type: none">background lighting should not be greater than a factor of 2 more than the display luminance	<ul style="list-style-type: none">light-emitting displays operate best under low background luminance conditions. Background lighting should be fairly uniform, and the luminance and contrast levels should be adjusted to the background lighting conditions

Table 4-1 continued

FACTOR OR INTEREST	INTERACTING FACTORS	SHOULDFEEL (1980)	HEAR (1980)	CARTER, HART, and SUTWAP (1981)	SHERR (1979)	COMMENTS
<ul style="list-style-type: none"> Resolution and screen resolution (the relation) - the related discernible detail in a visual display (screen resolution) - the number of raster scan lines on a screen 	<ul style="list-style-type: none"> viewing distance, luminance, contrast, character size, other legibility factors 	(NO RECOMMENDATIONS)	<ul style="list-style-type: none"> for legible lines, 2-5 min arc, (cf. Riberman, 1973) 2 resolution elements for most displays 	(NO RECOMMENDATIONS)	1-3 min arc minimum for any visual element	2-3 min of arc needed for clear visibility of visual element. The higher the screen resolution the better (generally). See also character subpage. U.S. standard: 525 lines. Europe standard: 625 lines.
<ul style="list-style-type: none"> Character size - the number of raster scan lines per character 	<ul style="list-style-type: none"> screen resolution 	<ul style="list-style-type: none"> 10-12 lines/character 	<ul style="list-style-type: none"> 10-12 lines/character 	<ul style="list-style-type: none"> 10-12 lines/character 	<ul style="list-style-type: none"> 7-11 preferred 10 optimum 	<ul style="list-style-type: none"> Substantial improvement on 10-12 lines per character.
<ul style="list-style-type: none"> Viewing distance from the viewer to the display screen. 	<ul style="list-style-type: none"> screen size, resolution, character size 	<ul style="list-style-type: none"> 20-30 inches 28 inches-common 	<ul style="list-style-type: none"> 28 inches-common 	<ul style="list-style-type: none"> 50cm-common (20 inches) 	<ul style="list-style-type: none"> 50-100cm-common (20-40 inches) 	<ul style="list-style-type: none"> Settings from 28-38 inches are good to calculate character sizes and resolution requirements. Viewing distance is usually under viewer control. The viewer is often within reaching distance of the display.

Table 4-1
SUMMARY OF RECOMMENDATIONS FOR VISIBILITY PARAMETERS

FACTORS OF INTEREST	INTERACTING FACTORS			COMMENTS	
	SHUTTLIFF (1980)	PEAR (1980)	CARL, HART, and STEWART (1980)	SHEPR (1979)	COMMENTS
<ul style="list-style-type: none"> • $L_{avg} = 2$ (photopic luminance) - the intensity of light emitted from a given area, the area being (1) the luminance of the background, (2) the luminance of the light of a rate of 1 lumen per foot-candle. The rate of change of the luminance is one unit per foot-candle (1 fcd) (1 fcd = 10 nits) 	<ul style="list-style-type: none"> • background lighting, resolution, contrast • 10-50 fL (34-171 nits) acceptable (character) 	<ul style="list-style-type: none"> • 10-100 fL (34-343 nits) acceptable (background) 	<ul style="list-style-type: none"> • luminance levels vary among display modes. • 45 nits minimum (character) • 80-160 nits preferred (character) • 15-20 nits (background) • luminance should be adjustable 	<ul style="list-style-type: none"> • 50 nits (14.6 fL) minimum (character) • the higher the background lighting, the higher the required luminance 	34-50 nits character luminance is minimum; higher levels are preferred. The lower the resolution and/or contrast, the higher the required luminance. The higher the lighting, the higher the required luminance. Luminance control is an important feature of display system.
<ul style="list-style-type: none"> • Contrast - ratio of luminance of a figure to the luminance of the background 	<ul style="list-style-type: none"> • luminance, resolution, flicker, background lighting • 10:1 under optimum conditions; as low as 2:1 for special conditions 	<ul style="list-style-type: none"> • 8.5:1 to 10:1 	<ul style="list-style-type: none"> • contrast level largely depends on background lighting • low contrast can be partially offset by higher luminance levels 	<ul style="list-style-type: none"> • 5:1 minimum • 10:1 preferred 	Contrast levels should be 8 to 10:1 minimum. Contrast control is highly desirable.

Table 4 continued

FACTOR OF INTEREST	INTERACTING FACTORS	SHORTLEFF (1980)	BEAN (1980)	CAPIN, HART, and STEWART (1980)	SHERR (1979)	COMMENTS
• Blur	• contrast, character size	• can be offset by higher contrast, larger characters	(NO RECOMMENDATIONS)	(NO RECOMMENDATIONS)	(NO RECOMMENDATIONS)	Shortleff is not too worried about the possibility damage of small amounts of blur (up to 20%). Solutions exist for blur but they are expensive.
• Character factors need to be considered in terms of the way in which they are presented or reported with help by the operator. The light adaptation of the eye.	• uniformity of background lighting, contrast, luminance	(NO RECOMMENDATIONS)	(NO RECOMMENDATIONS)	• remove distracting light sources • reposition the screen • increase the luminance • use anti-reflection shielding	(NO RECOMMENDATIONS)	Cakir suggests that anti-reflection shielding be used for video terminals as a general rule. Often, however, repositioning the screen and/or closing the curtains works just as well.

Sherr (1979) specifies 50 nits as an acceptable luminance. Depending on the levels of background lighting, unnecessarily high levels of luminance may cause viewer fatigue and discomfort (Vartabedian, 1971). Control over the levels of luminance is almost an essential feature and, fortunately, one that is commonly available on most visual display systems.

Contrast

Contrast refers to the difference in luminance between a figure and a ground on a visual display (e.g. between alphanumeric characters and the background screen). The ratio between the figure luminance and the ground luminance gives the contrast of the display:

$$C = \frac{L_f}{L_g}$$

where C = the contrast of a given display

L_f = the luminance of the figure (or
the maximum luminance on the display)

L_g = the luminance of the ground (or
the minimum luminance on the display)

Visual displays must reach an adequate level of contrast to allow the image to be clearly seen (Bryden, 1969). Sherr (1979) specifies a 5:1 contrast as minimum, 10:1 preferred. Bean (1980) concurs, suggesting contrast levels of 8.5:1 to 10:1. Shurtleff (1980) offers evidence that contrast levels can reach as low as 2:1 under special conditions, but that under sub-optimal conditions the contrast level may need to be as high as 18:1 (cf. Crook, Hanson, and Weisz, 1954.)

Because contrast is a basic variable and interacts with other factors such as luminance, background lighting, and blur, contrast control that allows adjustment to particular conditions is a highly desirable feature of a visual display system.

Resolution

'Resolution' is one of the most ambiguous terms in the human factors literature. Basically defined, resolution is the smallest discernable detail in a visual display (Sherr, 1979). That is, resolution answers the question, How many minutes of arc must a visual element subtend to be correctly and clearly seen? Sherr suggests that under normal viewing conditions a character must subtend 1-3 minutes of arc to be clearly visible on a CRT screen. The actual resolution of a particular display will vary depending in part on the luminance and contrast of the display. Several methods exist for measuring resolution, including the shrinking raster and television limiting techniques (cf. Sherr, 1979).

In addition to multiple techniques of measurement, further ambiguity enters in when 'resolution' is used in another sense meaning "the number of scan lines per character height", or in a third sense meaning "the number of scan lines on a CRT screen." To distinguish between these uses of the term, let us call the second kind "character resolution" and the third kind "screen resolution". There is general agreement that characters need 10-12 raster lines to ensure legibility. As for screen resolution, generally the more lines the better. Screens with low resolution have a problem displaying diagonal lines because the "stairstep effect"--the perceived discontinuity of the line--is more severe. However, the screen resolution is often set at a fixed standard. TV broadcasting sets the number of TV lines to 525 in the U.S. and to 625 in Europe. Since Sherr (1979) specified 1724 lines as the optimal screen resolution, the present situation is considerably less than optimal but adequate for many purposes.

Viewing Distance

In a review of legibility factors for electronic displays, Bean (1980) calculates all his recommendations to a viewing distance of 28 inches since most working environments place the worker approximately that distance away, within arm's reach of the screen. Shurtleff (1980) also uses 28 inches as a standard distance from the screen, but takes into account possible variations in distance at different viewing angles. The optimum viewing distance for a visual display depends on the screen size: the smaller the screen the shorter the desired viewing distance. Some allowance for variation from the optimum distance should be made since fatigue can more easily become a problem if the operator is required to maintain the same posture and viewing distance from the screen for long periods of time.

Viewing Angle

Seibert, Kasten and Potter (1959) provide evidence that no loss of accuracy or speed occurs at viewing angles up to 19 degrees off of center. Bean (1980) points out that viewing angle should not be a major problem for most single station operators because they will be able to adjust the angle to suit their preference. Shurtleff (1980), however, takes a different approach, considering the viewing angle to be an important consideration in the selection of appropriate display hardware. Shurtleff argues that his development of viewing area criteria "represents a unique and significant technical improvement in the approach to display selection" (Shurtleff, 1980, p. 112) and that they serve as a necessary adjunct to the classical visibility criteria reviewed in this section. Specifically

the viewing area criteria...guarantee wide-angle viewing by stipulating that the operator must be able to identify symbols when (a) working at any position on the display shelf and (b) working at a close-in position, e.g., arms on the shelf, or in a relaxed

position, e.g., sitting back in the chair with arms resting on the arms of the chair. These criteria provide operators with freedom of head and body movement necessary to avoid stretching, straining or slouching in attempting to identify symbology, all of which may result in eye strain and muscular fatigue.

Shurtleff, 1980, p. 112

For more detailed information concerning Shurtleff's approach to viewing area requirements, consult Shurtleff (1980), and chapter 5.

Viewing angle becomes particularly important when the display is designed for group viewing, or when the operator is not always stationed directly in front of the display. Such special cases in the working environment should be considered when determining visual display specifications.

Background Lighting

Background lighting refers to the light present in the working environment. Although the background lighting could be expressed in terms of luminance (light emittance) it is usually referred to in terms of illuminance (i.e., the amount of light received at a given point). Cakir (Cakir, et al., 1980) recommends a background illuminance of 300-500 lux (the non-metric unit in foot-candles) for a CRT display.

In general, light-emitting displays (CRT's, plasma panels, etc.) operate best under low levels of background lighting while light-controlling devices (e.g., LCD's) operate better under higher levels of background lighting. Bean (1980), in comparing different kinds of output devices, states that CRT's operate well under low to medium background lighting levels. CRT's can usually be used effectively under most levels of background lighting typically encountered in working environments.

Just as important as the amount of background lighting is the uniformity of the background lighting. The more uniform the background lighting, the more easily a display message can be read. Highly contrasting or irregular background lighting makes it difficult for the eye to accommodate to the display level of luminance (see glare below).

Direction of Contrast

Direction of polarity of contrast refers to the relationship between figure and ground. Displays may have a dark figure on light background or a light figure on a dark background. Most CRT's present light characters on a dark background.

probably more from convention than from documented research findings. Whether the dark background eases the eyestrain is at present unknown. Also, whether working environments with higher background lighting levels favor dark backgrounds is to our knowledge unknown. Shurtleff (1980) suggests that when viewing conditions are well below optimum, a switching capability may be useful, allowing the user to alternate between contrast directions at will. The general consensus, however, is that direction of contrast is not an important factor.

Screen Size

The size and proportion of the screen is of course an important consideration. If the display will be used as an input/output terminal, a smaller screen (12-15 inches) will usually be sufficient. Shurtleff (1980) suggests that larger screen sizes be used for military consoles, and larger still for group or remote viewing. In many cases, group viewing requires the use of projected displays.

In addition to the general purpose of the display, the amount of information that must be displayed at any given time is an important consideration in determining the appropriate screen size (see display capacity below).

Gray Scale

Gray scale is the term used to refer to the number of shades or steps of brightness perceived by the viewer. Sherr (1979), however, operationally defines "shades of gray" as a ratio of 1.4 between two levels of luminance, objecting to the inaccuracy inherent in the "human" definition above. Although people can discern up to 8 levels of gray under optimal conditions off line, this is not true for CRT viewing. Sherr (1979) points out that only 4 levels of gray can readily be distinguished on CRT's by humans (Sherr, 1979). Thus, following Sherr's usage of "shades of gray" to mean luminance ratios of 1.4, he recommends that "gray levels" used for coding purposes be two "shades of gray" apart.

Cakir, et al. (1980) note that the number of gray levels needed depends on the kind of task the user is engaged in. Many tasks require no more than two levels; for most graphics tasks, however, at least three levels of gray are recommended.

Flicker

Flicker is the perceived rapid dimming and brightening of a visual image caused by problems in the refreshing of the image. Small area flicker, such as the perceived movement of a displayed pinstripe suit, is more common than the flicker of the entire display. Prolonged exposure to flicker results in viewer irritation and fatigue (Oestberg, 1975). Two basic factors affecting the presence or absence of flicker are (1

the type of phosphor used on the screen and (2) the refresh rate (the number of refreshings per second) of the display (Gould, 1968). Phosphors differ in the length of time they persist in emitting light. Most phosphors commonly used on CRT's have low to medium persistence rates; longer rates are available but they cause smearing of motion graphics and scrolling. The shorter the persistence rate of the phosphor, the faster the refresh rate required to avoid flicker. Cakir, et al. (1980) sets the optimum range of refresh rate at 50-60 Hz. Since the standard refresh rate for TV receivers in the U.S. is 60 Hz, there is rarely a problem with flicker.

Jitter and Drift

Although flicker is the most commonly mentioned kind of image instability, it is probably the least frequent occurring. More often, visual displays are prone to varying degrees of jitter (rapid image movement) and drift (slow image movement) caused by voltage irregularities in the power supply. There are no easy solutions to image stability caused by problems in the power supply other than careful inspection and maintenance of the power source and connections to the display device.

Blur

Blur is a defocussing of the stroke edge resulting in a lack of sharpness in the visual image. It is expressed as the ratio between the observed width of the transition gradient from figure to ground and the width of the stroke.

Shurtleff (1980) suggests that the legibility of characters is not significantly reduced by blur levels of 20% or less. The harmful effects of blur can be offset by increasing the contrast level or by using larger characters.

Glare

Glare is a major problem encountered by visual display users in office environments. Cakir, et al. (1980) defines glare as disturbances in the background lighting or reflected disturbances on the screen that cause discomfort or impaired performance by disrupting the light accommodation of the eye (see also Oestberg, 1975). Mention was made in the discussion of background lighting of the harmful effects of irregular sources of light in the working environment. Cakir offers four suggestions to reduce glare:

- remove distracting light sources
- reposition the visual display screen
- increase the luminance
- use anti-reflection shielding

Cakir recommends that, as a general rule, anti-reflection types of glass be used on video terminals to reduce the reflected glare.

Summary of Visibility Factors

The most basic factors affecting the visibility of visual displays are the "classical" factors of luminance, contrast, and resolution. These three factors interact highly with each other; nonetheless, general recommendations can be made for each.

- The luminance of a visual display should be at least 34 nits (cd/m^2) and preferably between 50-160 nits. Luminance control is highly desirable.
- The luminance contrast of a visual display should be between 8:1 and 18:1. Contrast control is also highly desirable.
- Resolution: 10-12 raster lines should be used to form characters, resulting in characters subtending 15-30 minutes of arc from the eye. The standard screen resolution of 525 lines in the United States is adequate for general purposes; however, graphics uses may require screen resolution of 1100 lines or higher.

The following visibility factors are not so central but can still affect how well an image can be seen.

- The recommended viewing distance depends on the type of display (e.g., input/output, military console, or displays for remote or group viewing). For typical input/output devices, viewing distance is usually 24-28 inches or within arm's reach.
- Viewing angles as much as 19° off-center do not significantly affect display legibility; greater angles may require larger characters and wider spacing.
- The background lighting should usually be low to moderate for light-emitting displays (100-500 lux), and should be as uniform as possible to reduce glare.
- The direction of contrast is not an important visibility factor; the common use of white characters on black background is satisfactory.
- The size of the screen depends on the display's application: small screens (12-15 inches or smaller) are suitable for input/output displays whereas larger screens may be needed for remote or group viewing.
- For graphics displays, at least three shades of gray are recommended. Two shades of gray, however, are sufficient for most alphanumeric presentations. More than four shades of gray are probably unnecessary because of limitations of human perception.

The following visibility factors represent kinds of problems common to CRT screens particularly.

- Flicker, one kind of image instability, should be avoided by increasing the refresh rate, by using a phosphor with a longer persistence rate, or by decreasing the luminance. With a refresh rate of 60 Hz, common in the United States, flicker should not be a major problem. Jitter and drift can be corrected by stabilizing the current of the power source.

- Although blur levels of 20 percent are greatly harmful to legibility, increasing the bandwidth may help improve the sharpness of edges on a display, although at some increase in cost.

- Glare, another common problem, can be reduced by removing distracting background light sources, repositioning the display screen, increasing the display luminance, or by using anti-reflection shielding.

Legibility

The preceding factors have application to all kinds of visual images, whether graphic or alphanumeric. The following factors specifically affect the legibility of alphanumeric characters and the readability of written messages.

Table 4-2 follows the text structure and can be used as a concise summary of legibility factors.

Character Subtense and Height

Character subtense refers to the size of a character as measured by the minutes of arc it subtends from the eye. Sherr (1979) argues that since the minimum resolvable detail that humans can see is approximately 1 min of arc, the minimum necessary size of a 7-dot character is 7 minutes of arc. However, he specifies as a preferred character size between 16 and 30 minutes of arc. Cakir, et al (1980) generally agree, specifying a range of 15-22 minutes of arc as acceptable for alphanumeric characters. Bean (1980) cites two studies (Shurtleff, et al. 1977; Ketchel and Jenney, 1968) in setting 15 minutes of arc as a minimum character size. Shurtleff (1980) advises that under low levels of luminance (.01-.1 fL), 20 minutes of arc be used. However, for higher levels of luminance (10-50 fL), character size as low as 10 minutes of arc may be used. In general, Shurtleff allows a range between 10 and 37 minutes of arc, depending on the viewing conditions.

Table: 4-2

SUMMARY OF RECOMMENDATIONS FOR LEGIBILITY PARAMETERS

FACTORS OF INTEREST	INTERACTING FACTORS	SHURTLEFF (1980)	BENI (1980)	CARL, HART, and STEWART (1980)	COMMENTS
<ul style="list-style-type: none"> Character substance - the size of a character as measured by the subtended angle from the eye. 	<ul style="list-style-type: none"> viewing distance, resolution 	<ul style="list-style-type: none"> low luminance (0.1-1 fL) = 20 min arc med. luminance (10-50 fL) = 10 min arc 10-37 min arc acceptable 	<ul style="list-style-type: none"> 15 min arc (cf. Shurtleff, et al., 1966; Ketchel and Jenney, 1968) (at 28 inches viewing distance: .12 inches) 	<ul style="list-style-type: none"> minimum human requirements: 10-14 min arc 15-22 min acceptable (at 50cm viewing distance: 3.1-4.2 mm) for 5x7 matrix, 3.3 mm maximum 	<p>15-30 minutes of arc seems to be an acceptable size for characters, for translating into .12 to .24 inches at 28 inches viewing distance. Character size should be determined by the purposes of the display.</p>
<ul style="list-style-type: none"> Character substance - the size of a character as measured by the subtended angle from the eye. 	<ul style="list-style-type: none"> viewing distance, resolution 	<ul style="list-style-type: none"> low luminance (0.1-1 fL) = 20 min arc med. luminance (10-50 fL) = 10 min arc 10-37 min arc acceptable 	<ul style="list-style-type: none"> 15 min arc (cf. Shurtleff, et al., 1966; Ketchel and Jenney, 1968) (at 28 inches viewing distance: .12 inches) 	<ul style="list-style-type: none"> minimum human requirements: 10-14 min arc 15-22 min acceptable (at 50cm viewing distance: 3.1-4.2 mm) for 5x7 matrix, 3.3 mm maximum 	<p>15-30 minutes of arc seems to be an acceptable size for characters, for translating into .12 to .24 inches at 28 inches viewing distance. Character size should be determined by the purposes of the display.</p>

Table 4 continued

FACTOR OF INTEREST	INTERACTING FACTORS	SHURTLEFF (1980)	BEAN (1980)	CARLIS, HART, and STUMWART (1980)	SHERR (1979)	COMMENTS
<ul style="list-style-type: none"> Font--the style and proportion of alphanumeric characters. 		<ul style="list-style-type: none"> Lincoln/Mitre (L/M) 	<ul style="list-style-type: none"> no established superiority of any font avoid serifs upright rather than slanted characters acceptable: L/M, Leroy, MIL-M-18012 	<ul style="list-style-type: none"> upright rather than slanted characters 	(NO RECOMMENDATIONS)	Lincoln/Mitre, Leroy, and MIL-M-18012 are acceptable fonts; no font has been shown to be superior for CRT use.
<ul style="list-style-type: none"> Dot matrix size--the size (height x width) of the dot matrix used to generate characters as measured by the number of dots (5x7, 7x11, etc.) 	General viewing conditions	<ul style="list-style-type: none"> 5x7 marginal 7x9 or 7x11 preferred 	<ul style="list-style-type: none"> at least 5x7 	<ul style="list-style-type: none"> 5x7 acceptable 7x9 or greater--preferred 	5x7 or 7x9 acceptable	The 5x7 dot matrix is seen as marginal to acceptable, depending on the task requirements and other conditions. Otherwise, 7x9 or larger is preferred.
<ul style="list-style-type: none"> Character width--the ratio by which the characters 		<ul style="list-style-type: none"> 75% 	<ul style="list-style-type: none"> 50-100% 	<ul style="list-style-type: none"> 70-80% maintain a "correct balance between legibility of individual characters and readability of consecutive characters" (p. 102) 	<ul style="list-style-type: none"> 71-77% 71% (5/7) optimal 	75% aspect ratio is a good value. There is a broad range of acceptable values, however (50-100%).

Table 4-2 continued

FACTORS OF INTEREST	INTERACTING FACTORS	SHURTLEFF (1980)	REAR (1980)	CALP, HART, and STEWART (1980)	SHEER (1979)	COMMENTS
<ul style="list-style-type: none"> • <u>Stroke width to character height ratio</u>--the thickness of the stroke in relation to character height 	resolution, contrast, blur, character size	<ul style="list-style-type: none"> • 20% • 12.5 - 25% acceptable 	<ul style="list-style-type: none"> • 13.3 - 20% 	<ul style="list-style-type: none"> • 12 - 17% 	<ul style="list-style-type: none"> • 7 - 14% minimum • generally, use the thickest line possible • usually, not less than 10% 	Strokes 13-20% of the character height are acceptable. Generally, the thicker strokes the better.
<ul style="list-style-type: none"> • <u>Character spacing</u>--the spacing between characters on a row. 	luminance, character width to height ratio	<ul style="list-style-type: none"> • direct angle viewing: as close as 8-10% of character height • for extreme off-axis viewing of 45° or more: 25-50% of character height • for sub-optimal conditions: 25% 	<ul style="list-style-type: none"> • 10-15% of character height (cf. Shurtleff, 1972; Crook, et al., 1954) • between rows, 50% of character height 	<ul style="list-style-type: none"> • "restricting spacing is as important as... eye movement" (p. 100) • 20-50% of character width • between rows, 100-150% of character height 	<ul style="list-style-type: none"> • 25-65% of character height is acceptable 	15-50% of character height is a safe range. Cakir cautions about tradeoffs in spacing. Between word spacing is often one standard character length. Between row spacing should be 50-250% of character height.
<ul style="list-style-type: none"> • <u>Contrast</u>--the difference of color used in displays (green, yellow, blue, etc.) 	luminance, contrast, blur	<ul style="list-style-type: none"> • avoid extremes (NO RECOMMENDATIONS) (reds and blues) • use white, green, and yellow 		<ul style="list-style-type: none"> • selection criteria: <ul style="list-style-type: none"> --ease of focus --color contrast capability • yellow-green may be preferred • usually a matter of personal preference 	<ul style="list-style-type: none"> • all colors except blue are acceptable 	Black/white, yellow, and greens seem acceptable colors for alphanumeric displays, although color does not seem to be a major factor.

Table 4- continued

FACTOR OF INTEREST	INTERACTING FACTORS	SHUPPLEY (1980)	BEAN (1980)	CAULP, HART, and STEWART (1980)	SHEPR (1979)	COMMENTS
<ul style="list-style-type: none"> Letter case--all capital letters vs. mixed capitals and lower case letters. 	character size, resolution	(NO RECOMMENDATIONS)	<ul style="list-style-type: none"> mixed case preferred, however, no research exists for CPT's 	<ul style="list-style-type: none"> mixed case format is preferable; difficult with small matrices descenders should go below baseline of matrix 	(NO RECOMMENDATIONS)	<p>More research is needed on mixed cases on CPT's. For situations requiring the reading of lengthy prose passages, mixed case characters would probably be preferred.</p>

The actual size of the character on the screen is determined by the angular subtense discussed above and the viewing distance of the user from the screen. Hence, if 28 inches is assumed to be the viewing distance, characters of .12 to .24 inches would subtend 15 to 30 min. of arc. This seems to be a generally accepted range of character size.

Character Generation

Aside from the characters formed by raster scan lines, the three most common methods for generating characters are (1) dot matrix, (2) fixed stroke, and (3) random stroke. Dot matrix characters are formed by activating selected dots in a matrix, commonly 5 x 7 dots. Stroke characters are created by fine resolution strokes, produced in either a fixed or random format.

There seems to be no major difference in performance between dot matrix and random stroke characters. Fixed stroke characters require more processing time but are also legible and suitable for certain purposes. Shurtleff (1980) recommends that the dots in the dot matrix be as round as possible and as continuous as possible, resulting in continuous, smooth-appearing lines.

Font

Font refers to the style, shape, and proportion of the alphanumeric character set. In general, Bean (1980) has found no evidence to demonstrate superiority of one font over another for CRT applications. He recommends that serifs (extra curls and lines for accent) be avoided on CRT's and that upright rather than slanted characters be used to avoid the "stairstep effect" caused by diagonal lines on raster screens.

Regarding particular font styles, Shurtleff (1980) recommends the Lincoln/Mitre font because it has been empirically refined to reduce inter-character ambiguity. Bean (1980) finds acceptable the Lincoln/Mitre font, as well as the standard Leroy font and the MIL-M-18012.

Overall, several fonts could be used effectively for visual displays, the final decision resting primarily on aesthetic and logistical considerations.

Dot Matrix Size

The size of the dot matrix can range from 5 x 7 through 7 x 9, 7 x 11, 9 x 11 or larger. Shurtleff (1980) considers the 5 x 7 matrix to be only marginally acceptable; for less than optimal viewing conditions he recommends a 7 x 9 or

larger matrix. Bean (1980), Cakir, et al (1980), and Sherr (1979) all agree that the 5 x 7 matrix is acceptable for most purposes. Since the 5 x 7 matrix is probably the most common dot matrix, it would appear that its use is often appropriate. If viewing conditions are expected to be significantly below optimum, however, a larger matrix size should be considered. As display technology matures, the frequency of use of 5 x 7 matrices will decline. The cost differential between this and larger matrices is lessening rapidly and esthetic considerations greatly favor larger matrices. We therefore recommend that larger matrices be used over 5 x 7 matrices.

Character Width to Height Ratio

The character width to height ratio, also called the character aspect ratio, refers to the horizontal vs. vertical proportion of the individual character. Shurtleff (1980) suggests that the character width should be approximately 75% of the height. Bean's (1980) range of 50-100% is in general agreement with Cakir's (Cakir, et al. 1980) range of 70-80% and Sherr's (1979) of 71-77%. Buckler (1977) concludes that character aspect ratio is a relatively unimportant legibility factor, and that a rather broad range of values is acceptable.

Stroke Width to Character Height Ratio

How thick should the stroke be in relation to the character height? Again, researchers generally agree that the stroke should be between 12 and 20% of the character height. Sherr (1979) suggests that in general, designers should use the thickest lines possible, or at any rate, not less than 10% of the character height. Table 4-2 reviews other suggested ranges. The stroke width does not seem to be a critical variable affecting legibility provided a minimum width of about 12% is obtained.

Character Spacing

Character spacing refers to the amount of space between characters on a line. Based on evidence from Shurtleff and Alexander (1972) and Crook, et al, (1954). Bean (1980) recommends a character spacing range of 10-15% of the symbol height. Cakir, et al (1980) recommend that characters be spaced 20-50% of the character width. Sherr (1979) finds 25-65% of the character height acceptable. Shurtleff (1980) suggests that for direct angle viewing, characters can be

as close as 8-10% of the symbol height. For extreme off-axis viewing of 45° or more, 25-50% of the character height is recommended. In general, for suboptimal conditions, Shurtleff recommends spacing approximately 25% of the character height.

Spacing between lines or rows of characters should be at least 50% of the character height according to Bean (1980; cf. Streeter, et al, 1972). Cakir, et al (1980) recommend a more conservative 100-150% of character height.

Cakir, et al (1980) also make an important point relating to character size and character spacing. The optimum character size or spacing for legibility (i.e., recognizing individual characters) may not be optimal in terms of readability (i.e., comprehending sentences in prose format). There is a trade-off between the clarity of individual characters and the readability of long strings of words. Large characters with wide spacing may be very legible, but the number of eye movements required to read a passage may be greatly increased, thus lowering the passage's readability. This tradeoff should be kept in mind when choosing a particular character spacing level within the ranges specified above.

Display Capacity

Display capacity refers to the absolute number of characters that can fit within a given display surface. It is a function of (1) character size and spacing, (2) screen or display size, and in the case of CRT's (3) the size of the margins on the screen's edge. The display capacity can also be thought of as the product of the maximum number of lines times the maximum number of characters per line. Sherr (1979) specifies a system with 25 lines per display, 64 characters per line, resulting in a display capacity of 1600 characters (for color displays).

Although the capacity of a display is an important dimension, we do not mean to suggest that the formatting of content should be so densely packed in. The formatting of characters on the display is a completely independent issue and should follow guidelines from the literature in various fields of applied design.

Chromaticity

Chromaticity refers to the choice of color used as the basic hue for displays (green, yellow, etc.). Research has shown that yellow, green and white symbols near the center of the visual spectrum provided better performance than those at the extremes (blue and red). (Shurtleff, 1980; Alexander, et al, 1974; Snowberg, 1971). Krebs et al (1979) suggests the

following guidelines for selecting colors:

1. use no more than four colors
2. use red, green, and yellow to code alphanumerics
3. use blue for large symbols or where symbol identification is not a problem
4. use white for peripheral signals

Krebs (1978) also reported that red, white, and yellow symbols were read at a much higher rate than were green and blue symbols (Meister and Sullivan, 1969; Rizy, 1967). For colored signal lights amber, violet, and red were spotted more quickly and had the fewest identification errors both with laboratory and flight performance tests. Sherr (1979) finds all colors except blue acceptable. It is clear, however, that any color may be used successfully with adequate levels of luminance.

Letter Case

The case of alphabetical characters can be either all capitals (upper case) or mixed upper and lower case characters. For many purposes, uppercase character sets are adequate; however, for extensive prose reading, off-line research has shown that mixed case characters improve performance. Bean (1980) has found no research investigating mixed case characters on CRT's or other electronic displays. Vartabedian (1971) found that on electronic displays, upper-case words were more effective for visual search tasks, but that mixed case format was preferred for reading tasks.

More research needs to be done before we know fully the effects of case on electronic displays.

Summary of Legibility Factors

- Character size is the most important legibility factor. Alphanumeric characters should subtend at least 15-30 minutes of arc from the eye; thus, at 28 inches viewing distance, characters should be .12 to .24 inches in height.

- The dot matrix or random stroke methods of character generation are preferred over fixed stroke method. Fixed stroke characters are slightly less legible but are also acceptable.

- Any of a number of fonts are acceptable since insufficient research has been done on electronic displays. Fonts, however, should avoid serifs and slanted lines (to avoid the "stairstep" effect). Good fonts include the Lincoln/Mitre, the Leroy, and the MIL-M-18012.

- Matrix size: Five by seven matrices are marginally acceptable, although they are the most commonly used matrix size. Larger matrix sizes, such as 7 x 9 or 9 x 11, are preferred, especially when used with higher resolution screens.

- The character width to height ratio should be about 70-80%; however, it is not a major factor.

- Stroke to character height ratio: The stroke should be 12-20% of the character height; generally, the thicker the stroke the better.

- Character spacing should be at least 15-25% of the character height. Spacing between rows should be 50-150% of the character height.

- The display capacity requirement depends on the kind of task the display will be used for. A common display capacity will allow approximately 1600 characters to be presented on the screen.

- Chromaticity has not been shown to be an important factor.

- Letter case is a factor not well investigated on electronic displays. Hard copy research suggests that mixed case is preferred for prose reading tasks; however, this finding has not been replicated on electronic displays.

CHAPTER 5

DEVELOPMENT OF MATERIALS

Each of the major system types has different development procedures associated with it. These different development procedures have implications which must be taken into account in the analysis of the hardware. This chapter analyzes the various development procedures.

Analysis of Army Training Materials

There are three general classes of Army training materials: school curriculum, exported (extension) training, and embedded training--Computer Assisted Instructor (CAI) or Computer-Managed Instruction (CMI) embedded in operational equipment. The first category consists of course notes, handouts, overheads, and so on. Exported training materials include Training Extension Course (TEC) lessons, Educational Television (ETV) programs, Army Training Literature Program (ATLP) manuals, Skill Performance Aids (SPA), Army Correspondence Course Program (ACCP) sub courses, and Skill Qualification Test (SQT) materials. Embedded training materials take the form of computer programs (except for materials used in CMI). The major concern of this study is with exported training materials, although embedded training programs obviously have direct relevance.

Exported training materials can be classified into three major types with respect to electronic delivery systems:

- 1) TV safe materials - This includes audiovisual TEC lessons and ETV programs which can be developed in videodisc format relatively easily.
- 2) Standard printed matter - This includes all printed TEC lessons, ATLP, and SPA manuals, ACCP material, and SQTs.
- 3) Oversize printed matter - This includes documents such as large schematics, charts or maps which are not of a standard size.

The second category of materials (i.e., standard printed matter) includes a number of different components such as text, line illustrations (diagrams), charts, photos, and flowcharts. Table 5-1 presents some preliminary data on the relative frequency of different components in selected Army training materials. Note that the categories are not exclusive (e.g., a single page could include a chart with an illustration in it). This data suggests that illustrations are the prominent component in technical manuals and are quite frequent in ATLP materials such as training circulars or field manuals. The data also suggests that photography is used quite infrequently.

TABLE 5-1
Frequency of Components in Army Training Manuals

Item	Text	Graphics (All Types)	Panels	Dials	Tables	Flow	Photos
TM 11-5995-208-24	42	68	-	3	8	-	-
TM 9-1005-206-10	32	64	15	2	16	6	-
TM 9-6920-484-12	15	72	18	6	14	5	-
TC 6-40-1	69	46	-	-	20	1	-
FM 6-30	89	55	-	-	16	2	-

Text deserves some additional comments. Text is common in two forms: typed or typeset. Typed print almost always reads across the full width of the page while typeset print is often set in two columns down the page. Generally a manual will be either typed or typeset but sometimes both are found in the same manual (usually not on the same page however). Caution and warning notes in manuals are boxed and usually only one column in width. Notes, as well as labels and call-outs are typically in bold face.

Color is used in a number of different ways in printed matter. Its primary use is to highlight or isolate a piece of equipment or an important heading or sentence. For example in an illustration of a piece of equipment, a particular part being discussed will be colored, or an important piece of text (such as a warning) may be in color or surrounded by a color box. Color is also used to draw attention to important information and to improve the motivating qualities of the material (i.e., by making it more visually stimulating).

The implications of this analysis to the development model are as follows: Training materials which are already in T.V. safe form or designed for embedded training involve relatively straightforward transformations for electronic delivery systems (EDS). Materials which are in print form (either standard or oversize) require a much more extensive transformation process if they are to be converted for EDS use. The variables of importance in such a transformation process are the complexity and size of illustrations and charts, the nature of the print (one column or two), and the presence of color. These variables affect the capabilities needed to record and display materials currently in print form.

Analysis of Army Training Materials Specifications and Regulations

A second important input to EDS development models is the existing specifications and regulations for Army training materials. Table 5-2 provides a partial list of some of the documents applicable to the development of Army training materials. Many other specifications, standards, and regulations exist and are referenced in the documents listed in the table.

These documents define the organization and structure of Army training manuals. The structural specifications (i.e., what sections must be present) would apply to the development of EDS materials. However, specifications and guidelines regarding the design of illustrations, page size, type size, indexing schemes, and text preparation would not apply in their present form to EDS materials. In addition, there are a large number of dynamic and interactive capabilities which EDS presentations would allow which are not covered in the present regulations. For example, text screens can be built up on a display, scrolling if possible, and text can be made to blink or move. Thus some aspects of current specifications guidelines will not apply to EDS, and some EDS capabilities will require new specifications.

TABLE 5-2
Documents Applicable to the Development of
Army Training Materials

MIL-M-38784A	Manuals. Technical: General Style and Format Requirements
MIL-M-63001	Manuals. Technical: Repair Parts and Special Tools List
MIL-M-63004	Manuals. Technical: Preparation of Lubrication Orders
MIL-M-63035	Manuals. Technical: Front End Analysis
MIL-M-63036	Manuals. Technical: Operator's, Preparation of
MIL-M-63038A	Manuals. Technical: Organizational or Aviation Unit, Direct Support or Aviation Intermediate, and General Support Maintenance
MIL-M-63040	Manuals. Technical: Preparation of Extension Training Materials
MIL-M-63043	Manuals. Technical: Missile System Equipment Check Procedures
MIL-M-63044	Manuals. Technical: Missile System Equipment Unit-Under-Test (UUT) Procedures
MIL-M-63049	Manuals. Technical: List of Applicable Publications (LOAP)
MIL-M-63050	Manuals. Technical: Components of End Item. Basic Issue Items. Additional Authorizations, and Expendable Supplies and Materials Lists
MIL-HDBK-63038-1	Technical Manual Writing Handbook
MIL-HDBK-63038-2	Technical Writing Style Guide
TM 38-750	The Army Maintenance Management System
TC 21-5-3	TEC Management Instructions
AR 611-201	Enlisted Career Management Fields and Military Occupational Specialties
TRADOC REG 350-100-1	Development, Implementation and Evaluation of Individual Training
TRADOC PAM 350-30	Interservice Procedures for Instructional Systems Development
TRADOC REG 351-2	Skill Qualification Tests (SQT) Policy and Procedures

The capabilities of EDS could also change the economics of developing training materials. For example, the use of color is generally discouraged insofar as it requires approval of the Office of the Adjutant General (AR 310-1). If material is to be converted to videodisc format and presented via color TV monitors, the use of color is no more expensive than monochrome and therefore may not need to be proscribed as such. Similarly, line illustrations are recommended rather than photographs, primarily because of the additional expense and difficulty in using photographs in print media.

However, if material is to be converted to videodisc format, it may be as easy and no more expensive to use photographs as illustrations (depending upon the display resolution required). If materials are prepared, stored, and distributed in electronic form, this will undoubtedly affect regulations concerning revision. Thus, the use of EDS may change the rationale underlying existing specifications and regulations depending upon the type of conversion approach followed (see next section).

Development Models for Existing Materials

Three types of development models for converting existing materials to EDS form are needed: one for T.V. safe-type materials (i.e., TEC audiovisual lessons, ETV programs), one for printed materials, and one for embedded training programs. This section outlines models for each of these three types.

TV Safe Materials. Figure 5-1 presents two possible models for converting TEC audiovisual lessons to videodisc format for use in an EDS. In the best case, the 16mm film master of the TEC lesson is available and can be converted to videotape relatively inexpensively and automatically. In the worst case model, a tape must be made from the original camera ready mechanicals (CRM's) and errors are assumed. The cost difference between the best case and worst case models is estimated to be a factor of four times. Conversion of an ETV program is relatively simple and involves only three steps: (1) producing a 3/4" dub tape with visual SMPTE, (2) producing an edit log for review of tape, and (3) editing the master tape to disc. The addition of new still frames represents an additional editing step.

WICAT has successfully converted a TEC lesson from 16mm film form to a 2 inch master tape. This process required about 2 hours of studio time for a half hour lesson -- longer than had been expected. Considerable editing time was required for the pauses in the lesson. An additional frame or text overlay must be made for each pause ("press next to continue"). Presumably in an electronic delivery system, this pause would be associated with the entering of a response and feedback. This experience with TEC conversion suggests that the costs may be closer to the worst case than the best case estimates even when converted directly from 16mm film.

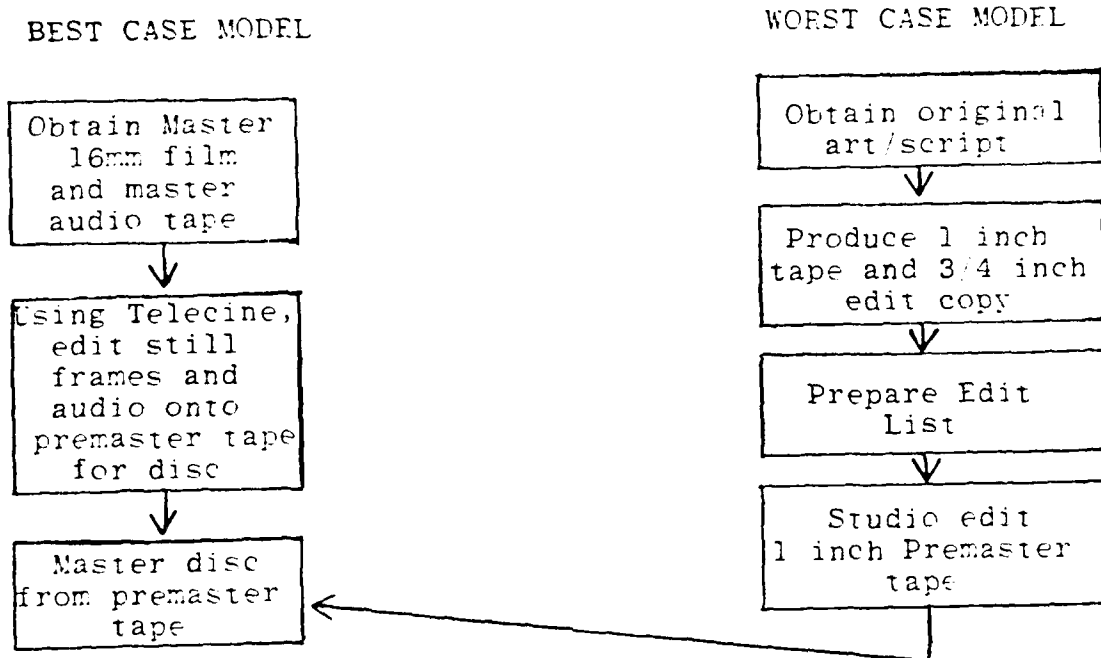


FIGURE 5-1.
Conversion of TEC Lessons to
Electronic Delivery System Form

Print Materials (ATLP, SPA, SQT/ARTEP, ACCP). There are a variety of alternatives for the conversion of print materials to FDS form. Figure 5-2 presents the manual formatting approach. First an edit log is made from the CRM's. The text is retyped on a studio quality character generator and stored in video form. The original art is either shot as is or made into multiple overlapping shots via zooming, in order to achieve sufficient resolution with an NTSC system. The text and art are then edited together on a premaster tape which can then be mastered in videodisc form. The delivery system uses low resolution color monitors.

Figure 5-3 presents a second approach: as-is conversion using high resolution input-output. The original materials are shot page-for-page by using a high resolution camera. The camera output is either converted to digital form via digitization, sampling, or FM encoding. The digital information is then stored on either magnetic or optical disk. The information is then converted or decoded back to analog form for display on a raster type high resolution TV monitor, or displayed digitally on a high resolution vector or storage display (bypassing the conversion/decode step).

Experiments 3 and 4 of the present study investigated the limits of the reformatting and "as is" approaches. It was found that reformatting text and graphics for NTSC video typically requires a minimum of four to five video pages for each text page. Moreover, zoom-ins for graphics must be so close that an "establishing" shot is often needed to orient the user to the relation of each portion of the graphic to the whole. In order to transfer an entire text page to video format intact, a minimum of approximately 1000 TV scan lines was required, at a 20MHz bandwidth. This is far above the 525 scan lines at 4.2MHz available on U.S. broadcast TV.

A third approach (automatic reformatting) is shown in Figure 5-4. In this method, an addressable camera is used to digitize the materials. Under software control, the original materials can be reformatted during the scanning process (i.e., by selectively reading parts of the page) or can be digitized completely as is and reformatted before storing. The stored information is then converted back to analog form and displayed on a low or medium resolution monitor. In this approach a page of full width text is scanned in order to divide it into quadrants. This is accomplished by spotting word boundaries approximately half way across each line. Figure 5-5 presents the process schematically. The first line is divided into two parts, A and B. These are then presented sequentially down the page. The same applies to other full page width lines.

This last alternative is being investigated by the Illinois Institute of Technology under contract to ACTO. A first pass is done in low resolution to spot breaks and to generate computer commands. Then a second pass at 2000x2000 resolution is performed to digitize and reformat the page. The full process takes from 20 seconds to several minutes, depending on whether the original page is already in columns or in full width text. Graphics are digitized separately.

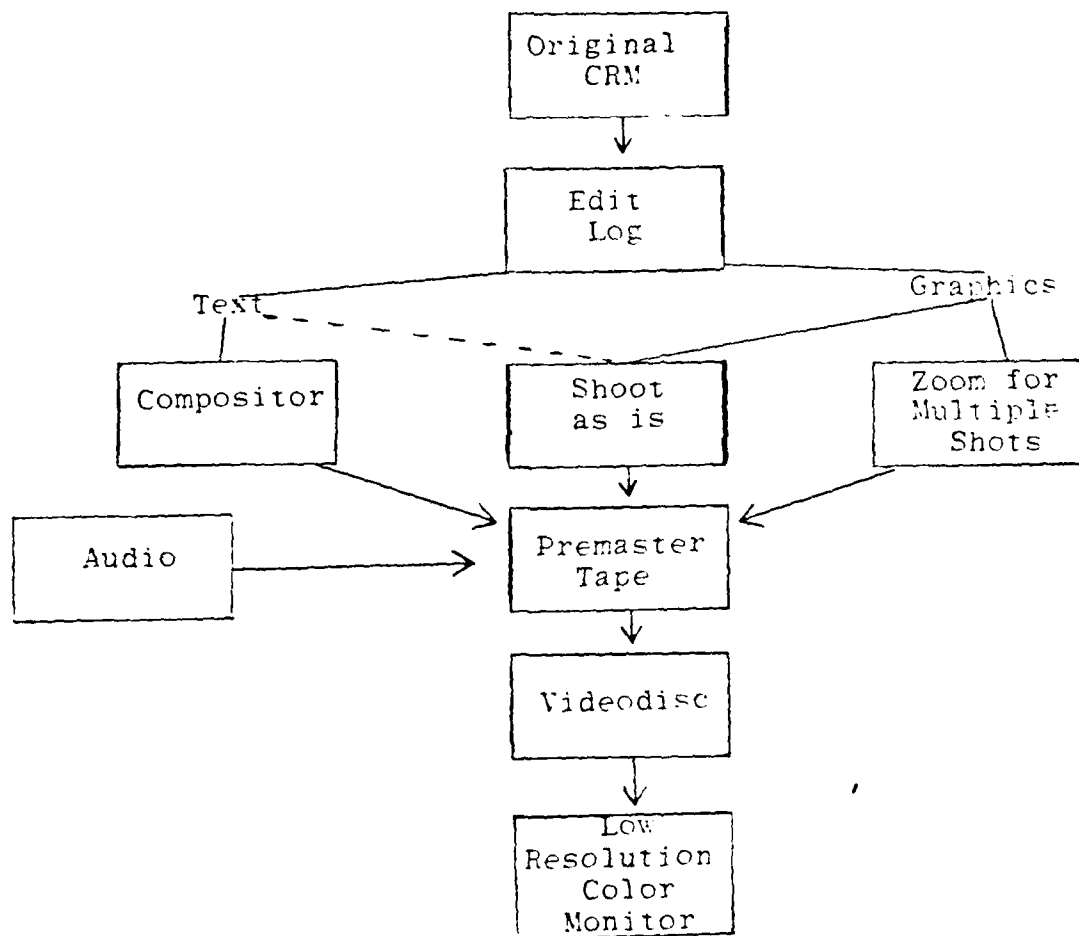


FIGURE 5-2
Manual Reformatting Approach

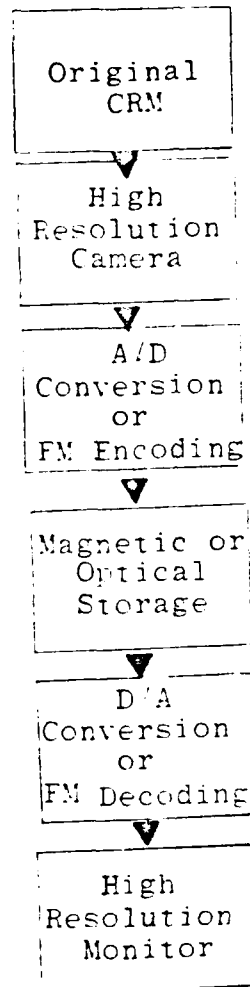


FIGURE 5-3
As-Is Approach

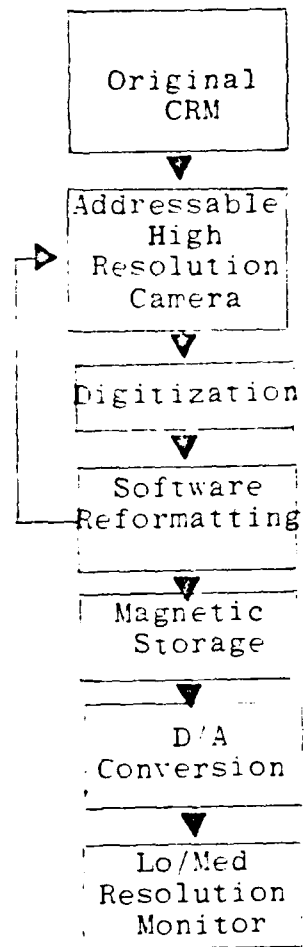


FIGURE 5-4
Automatic Reformatting Approach

A1	B1
A2	B2
A3	B3
A4	B4
A5	B5
A6	B6
A7	B7
A8	B8

ORIGINAL

A1
B1
A2
B2
A3
B3
A4
B4
:

REFORMATTED
VERSION

FIGURE 5-5
A Means of Automatically Reformatting
Full Pages of Text

Each of the three alternatives for print conversion is technically feasible but has not yet been operationally demonstrated. The manual reformatting approach is a labor-intensive procedure. For example, WICAT reformatted a full page of typeset text from a field manual using a compositor. This took 67 minutes from start to completion and resulted in 22 video frames. While this is likely to represent a worst case situation, it is clear that manual reformatting will be time consuming.

The conversion and delivery equipment required for the as-is approach is relatively expensive (conversion equipment is \$20-\$50,000; a high resolution black and white monitor is \$1,000); a huge amount of memory is required to digitally store text and graphics unless character recognition is used and graphics are converted and stored as programs. This would add a great deal of complexity and expense. However, the conversion process would be quite fast since it simply involves shooting the existing CRM's. In addition, a much greater amount of information can be presented using the high resolution monitors.

The automatic reformatting approach also involves expensive conversion equipment (\$20-50,000) and decreases the labor required for conversion. In addition, low or medium resolution monitors can be used for delivery, making this approach less expensive in terms of delivery equipment than the as-is approach. However, because the information is reformatted, many more pages of information result than the originals, and this might result in greater training time.

Until each of these alternatives is operationally tested, it is impossible to determine the best approach for conversion of print materials to electronic form.

Embedded Training Materials. Embedded training materials (CAI or CMI) exist in the form of computer programs for lesson presentation, testing, or student management and are presented on operational equipment. Provided that these materials are in languages available on the electronic delivery system and do not require the weapons system hardware, they can be used as-is. If the language or hardware is not available, then the code must be converted to a language which is used. If the embedded materials also involve print or audiovisual media, or if audiovisual media are to be added (e.g., on a videodisc) additional programming is required to include the frame addresses in the programs.

Obviously, a complex simulation program involving graphics would require the equivalent capabilities in the new delivery system hardware and software. If these capabilities were not present, it is possible that the graphics could be redone as stills or animation sequences and stored on the videodisc. Clearly this type of conversion would be expensive and complicated.

Recorded Audio vs Synthesized Audio. At the present time, recorded audio provides better quality, and is less expensive than synthesized audio. Note, however, that synthesized audio could potentially save development costs since it would be unnecessary to hire an announcer to read a script. The script could be coded into a program and automatically generated from a digital representation. In addition, synthesized audio might make revision quicker and less expensive since changes could be made to the digital representation rather than having to re-record. For most audio sequences, recording is presently the most cost/effective means. However, there are some situations, particularly with respect to feedback messages for generated items (e.g. "The answer 36 is incorrect . . . the correct answer is 32"). Here synthesized audio may be a viable alternative to recorded audio.

Input Mode. The development costs associated with input mode are primarily software costs. For simple input (yes/no, A, B, C, D, etc.) the programming is about the same. Thus, the code required for processing a single key entry is about the same as that required to identify an X-Y position on a touch screen, and about the same as testing a match for a single word utterance from a voice input system. Input from special purpose controls often involves analog to digital conversion.

The use of a high level authoring system which automatically generates the appropriate code for handling input may eliminate the differences between input modes. Of course, the time required to develop the authoring system would reflect the differences.

Development Models for New Materials

The previous section dealt with development models for conversion of existing materials. However, consideration should also be given to models for developing new materials for electronic delivery systems.

Figures 5-6 and 5-7 depict some of the alternative methods possible for producing materials. Text can be entered into a word processing system or a video character generator for digital or video format respectively. From the word processor, the materials can be printed out and distributed in paper form, or stored in magnetic form for electronic distribution and display. Graphics can be shot with a camera (original art or photographs) for video format and videodisc storage, digitized for magnetic storage, or computer generated (i.e., animation) for magnetic storage.

The dotted lines in Figures 5-6 and 5-7 show possible but less likely alternatives. For example, while videodisc is likely to be physically distributed, the information it contains could be distributed electronically. Digital information could be stored on videodiscs. Although magnetically stored information can be physically distributed, it is more likely to be distributed electronically (at least in the mid to late 80's). Finally,

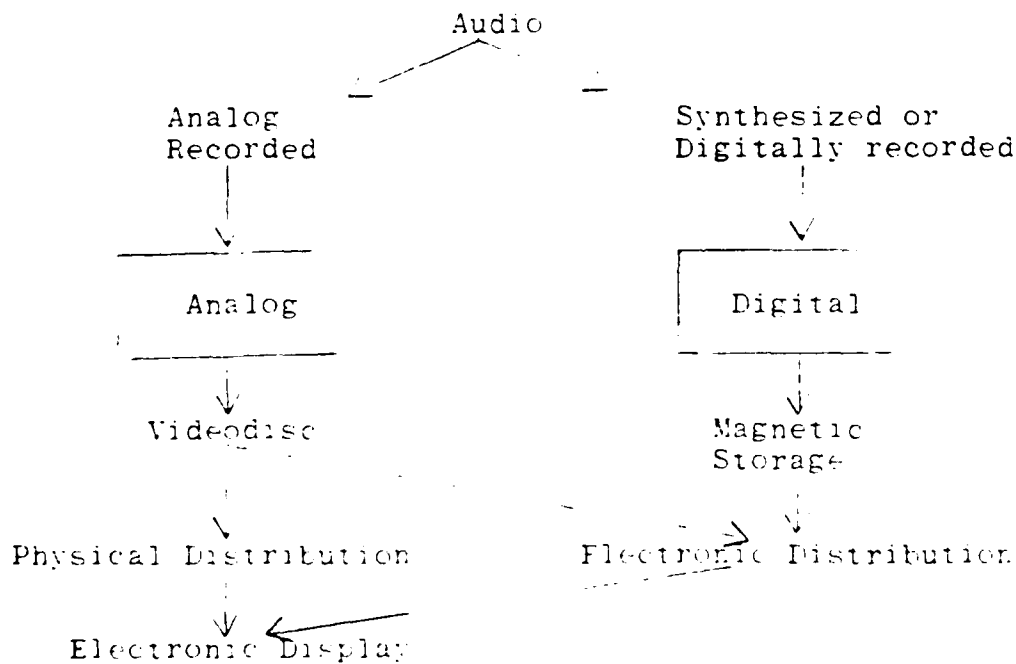
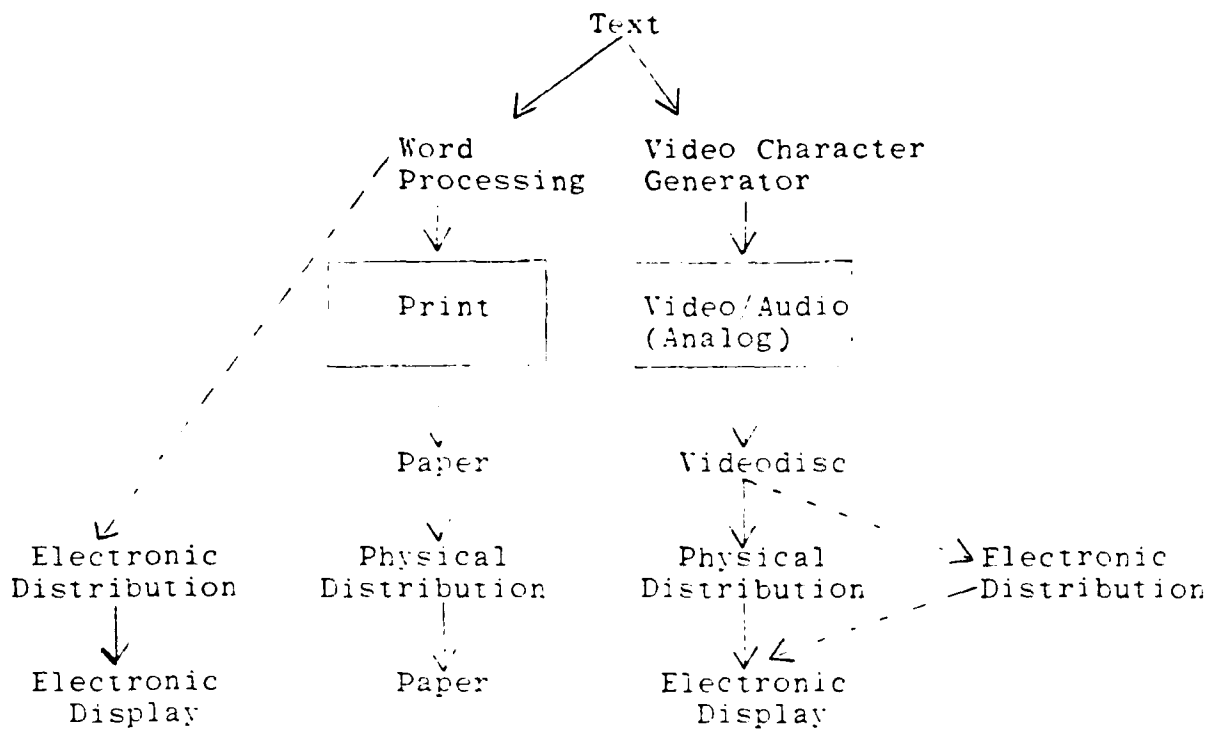


Figure 5-6. Alternative Methods for Creating New Materials For Electronic Delivery Systems: Text and Audio

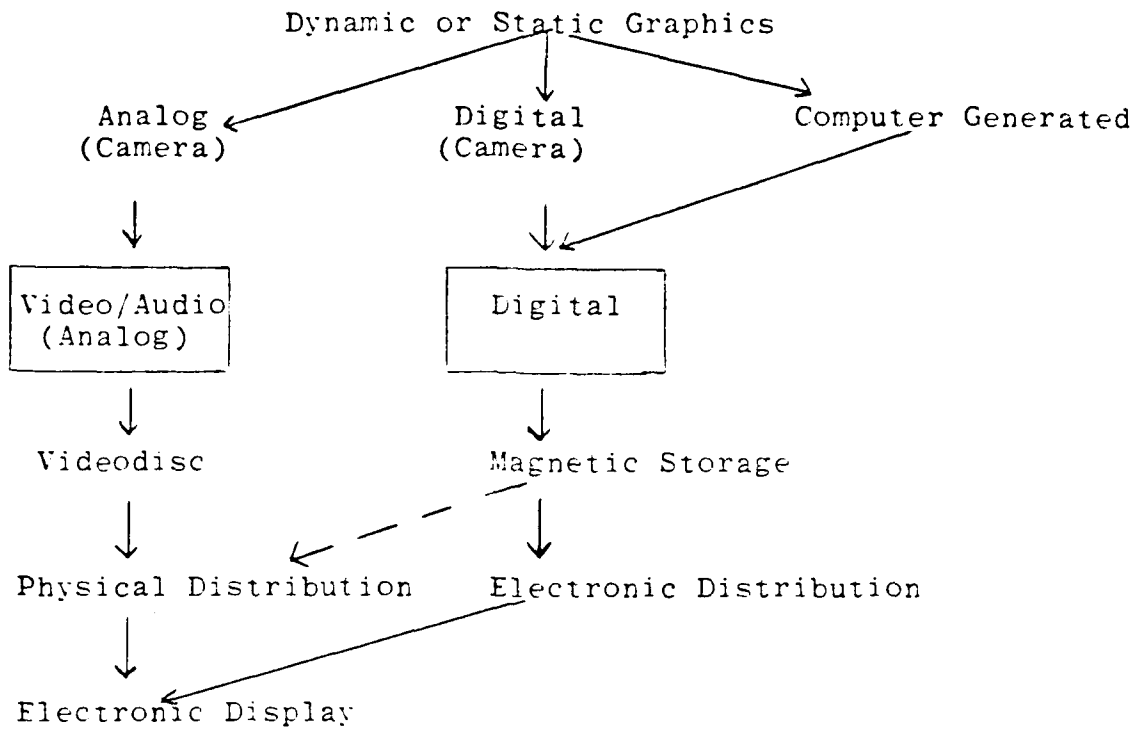


Figure 5-7. Alternative Methods For Creating New Materials For Electronic Delivery Systems: Graphics

note that there are many alternatives not shown--indeed print, video and digital information can be converted as discussed in the previous section.

All of the possible approaches presented in Figures 5-6 and 5-7 are likely to be viable for different applications and development scenarios. For the development of TEC materials to be stored on videodiscs and delivered electronically, a sensible approach is to prepare the text by video character generator, record the audio, and shoot static and dynamic graphics via camera so that all materials are in video form. For the development of training manuals, it might be best to create the text via word processing, and produce the graphics via digitization

or computer so that all materials are in digital form for electronic or physical (paper) delivery. The development of a simulation program for embedded training which involves both videodisc and computer generated displays is likely to involve the use of a video character generator, synthesized audio, and both camera-produced and computer-generated graphics.

Thus, different development approaches are likely to be required (or most cost-effective) for different training applications. These different development approaches may be made relatively transparent to the developer by use of a sophisticated authoring system. Such an authoring system allows the developer to create and modify a lesson (including graphics and interactive sequences) at a fully equipped authoring station without concern for the details of how the materials are actually developed. The author enters the lesson content, prepares static and animated graphics, specifies audio sequences, and describes the interactive logic. The authoring system then aids the necessary intermediate production steps for producing print, video, or digital materials.

Chapter 6

INPUT DEVICES FOR ELECTRONIC DELIVERY SYSTEMS

Input devices are used to enter data or control electronic delivery systems. The most common input device is the computer keyboard. However, a wide variety of other input devices have been developed and used for particular applications. Many of the input devices discussed below could be used for different tasks within each scenario. The selection of the input devices most appropriate for each scenario depends on the particular tasks, data input constraints, and environmental situations in which the device will be used.

Alternative Input Devices

A representative list of alternative input devices includes keyboards, keypads, voice recognition systems, touch panels, light pens, joysticks, trackball, mouses, graphics input tablets, switches, optical character recognition systems, optical scan sheet readers, punched card readers, magnetic card readers, and bar code readers. Many of these devices have wide applications for electronic delivery systems, but some are restricted to only a few cases. Here we address those devices with the widest applications. Figures 6-1 through 6-7 provide a sample of the input devices.

Sherr (1979) presents the major comparison parameters for graphic input devices. That work indicates that the trackball can provide the best resolution, linearity, and ruggedness. The joystick emits pulses based on the deviation angle of the joystick from an upright position. The trackball, however, emits pulses whenever it is rolled. Data tablets can provide good resolution and the writing and drawing motion is very natural. Light pens are easy to use but have limits in speed, accuracy, and ruggedness.

Comparisons Among Input Devices

There is little research comparing the effectiveness and efficiency of alternative input devices across a wide variety of input tasks. The research which has been done does yield some tentative comparisons among various input devices.

Voice input should be more effective and efficient for interactive problem solving than keyboards or handwriting (Chapanis, 1975, 1976; Chapanis, Ochsman, Parrish and Weeks, 1972, 1977; Ford, 1977; Weeks and Chapanis, 1976).

Hanes and Kinkad (1971) found that optical character recognition systems allowed faster data entry and fewer errors than keyboard input. Touch tone and digit keypads are very efficient and effective for numerical input (Conrad, 1966; Conrad and Hull, 1968). Touch panel input is faster than keyboard input for entering cursor control information (Earl and Goff, 1965).

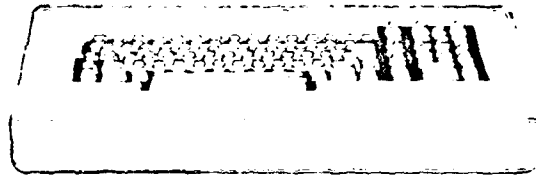


Figure 6-1. A typical keyboard.

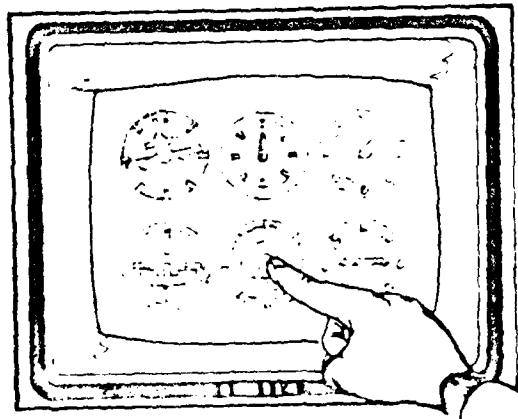


Figure 6-2. A typical touch panel.

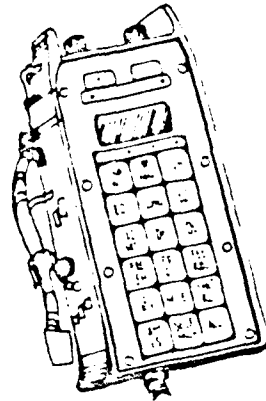


Figure 6-3. A typical militarized keypad (embedded in a data entry device).

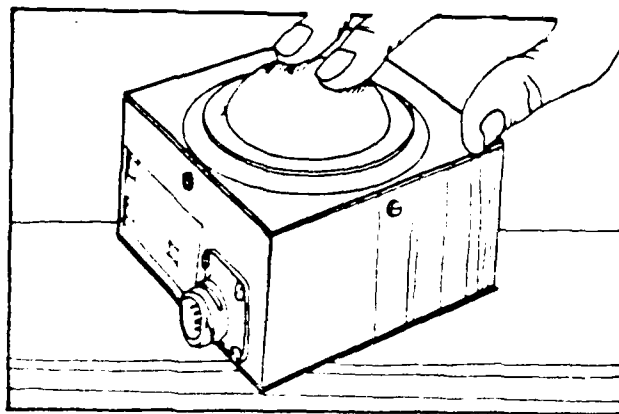


Figure 6-4. A typical trackball.

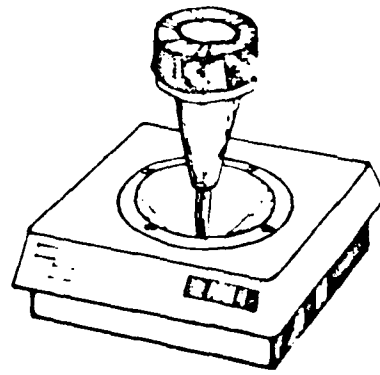


Figure 6-5. A typical joystick.

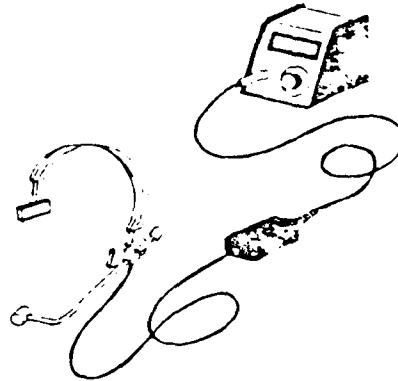


Figure 6-6. A typical voice input device.

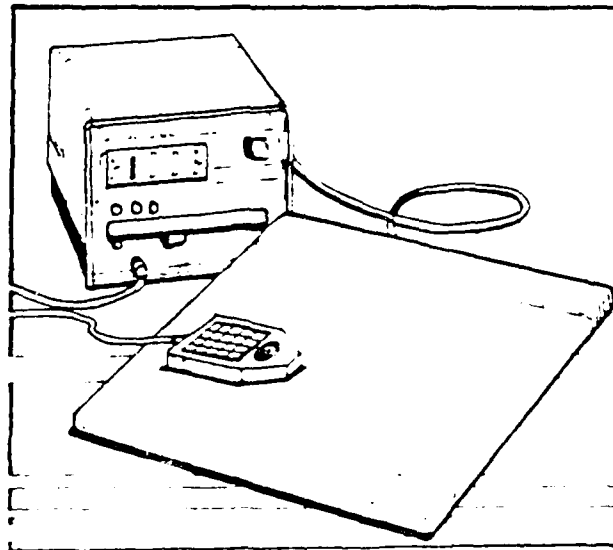


Figure 6-7. A typical mouse and a graphics tablet (mouse is separate from tablet, but some tablets include a mouse-like "puck").

Among graphics input devices the mouse was fastest with fewer errors when compared with the lightpen, joystick, trackball, knee control, and graphics tablet (Card, English and Burr, n.d.; English, Englehart and Huddart, 1965; English, Englehart, and Berman, 1965).

Touch panels were faster than rotary dials (Heglin, Sabeh and Driver, 1972). Light pens and light guns were faster than keyboard for cursor control (Goodwin, 1975). The trackball gave the best overall control for drawing straight lines and circles when compared with light pens and joysticks (Irving, Horinet, Walsh, and Chan, 1976).

Engel and Granda (1975) provide an excellent summary of the comparative advantages and disadvantages of alternative input devices. Table 6-1 presents their findings.

Table 6-1
Comparison of Alternative Input Devices
(Engel and Granda, 1975)

Lightpen

Advantages:

- Fast for simple input.
- Good for tracking moving objects.
- Minimal perceptual-motor skill needed.
- Good for gross drawing.
- Low error rate, if properly implemented.
- Efficient for successive multiple selections, if positions known.
- User does not have to scan to find a cursor somewhere on the screen.

Disadvantages:

- Does not feel natural to user, like a real pen or pencil.
- Lacks precision because of the pen's aperture, distance from the CRT/screen surface, and parallax.
- Contact with the computer may be lost unintentionally.
- Frequently required simultaneous button depression can cause slippage and inaccuracy.
- Must be attached to terminal, which may be inconvenient.
- Glare problems if tube tilted to optimal angle.
- Fatiguing if tube 90 degrees to work-surface.
- Must make bright target on screen, unless the screen is already lighted.
- One-to-one input only (no vernier capability).
- Cumbersome to use with alternate, incompatible entry methods such as keyboard.
- Awkward or difficult for left-handed users.
- Obstructs portion of screen when used.
- Tends to be used for purposes other than originally intended (for example, for key depression).
- Care must be taken to provide adequate "activate" area around choice point.
- Slow, if many logical, scattered choices are to be made.

- Cannot be used on gas panel

Joystick/Track(bowling) Ball/Mouse

Advantages:

- Very accurate with high resolution.
- Can be used comfortably, with minimum arm fatigue.
- Does not cover parts of screen in use.
- Expansion/contraction of cursor movement possible.
- Joystick and track ball can be attached to and used near to the keyboard.
- Ball excellent for three-dimensional rotation of objects (not of cursor).

Disadvantages:

- Slower than lightpen for simple input.
- Must be attached, but not to display.
- Unless large joystick, inadequate control/display ratio with positional control. Ratio adequate with rate control. The displacement of the stick controls both the direction and the speed of cursor movement.
- Difficult to use for free-hand, graphic input.
- Inconvenient to have integrated "activate" switch with ball.
- Mouse requires additional workspace surface.
- Mouse requires removal of hand from keyboard.

Stylus with Tablet

Advantages:

- Excellent for graphic entry.
- User works on horizontal surface.
- Multi-purpose input device
- Expansion/contraction of cursor movement possible.

Disadvantages:

- Extra space required on work surface.
- May have coordination problem due to displacement of visual feedback of motor activity.

Keyboard (Function Keys)

Advantages:

- Close at hand if user typing.
- OK for text editing.

Disadvantages:

- Fine resolution difficult.
- Limited control in most cases, usually in increments of one character.
- Limited motion unless chorded input acceptable, but then requires long training time and skill to operate, and the error rate is high (10%);

- Cannot enter graphics.

Engel and Granda (1975) summarize their recommendations about the various input devices as follows:

"While this list of advantages and disadvantages is not exhaustive, conclusions may be drawn from it which can be verified with future research. The light and selector pens have few of the desirable features which were listed in the introductory section of this report; they have many disadvantages that would preclude them from being used effectively and effortlessly by users in a wide variety of applications. The bowling (track) ball, unless very large, would probably be too slow, given the recommended requirements for control/display ratio. There is also the problem of placing an "activate" switch on or under the ball. The mouse must be used on a flat work surface, which may be impractical. In addition, a user would have to remove the hands from the keyboard to use it (assuming that alphanumeric entries are necessary)."

"The stylus with digitizer is versatile, but requires extra space on the workspace and probably could not be moved around easily (for example, away from the screen). Keyboard controls are sufficient for rough positioning, but some other method is needed for precise cursor placement, especially when a customer is paying for an all-points addressable feature."

"From an overall human factors viewpoint, the joystick appears to be the best control method, in ease of use, in control response characteristics, and in range of applications. It has long been used as a control device, and a number of satisfactory guidelines and design parameters exist for its use. Its responses can be internally modified so that a user can control externally the relationship between control movement and display movement (referring, for example, to correspondence to a vernier capability). It can be attached by a connecting cable to the terminal, and the user is not tied to a given distance from the screen. It is accurate, especially with vernier capability."

Additional research on graphics input devices can be found in Shapley and Shipley, 1970; Prince, 1971; Ritchie and Turner, 1975; Walker, Gurd and Drawneek, 1975.

Ramsey et. al., (1978) and Ramsey and Atwood (1979) provide an excellent summary of the research comparing alternative input devices. Table 6-2 presents their results.

The table points out that the selection of an input device is dependent on the particular input task and environment in which the device will be used. There does not appear to be a best input device for all tasks and situations. Foley and Wallace (1974) and Wallace (1976) suggest the need for modular, virtual,

Input Device	Comments	Principal References
Keyboard	<p>The vast majority of past research on input devices has dealt with keyboards. Reasonable and fairly detailed guidelines exist with respect to the physical properties of keys and keyboards and to a lesser extent - their layout, logical properties, operating procedures, etc. Guidelines for alphabetic keyboards are particularly good, and those for numeric keypads are reasonable. Function keyboards are rather system-dependent; guidelines can specify their physical properties, but can only suggest methods and basic principles for function selection and layout. It is not clear that chorded keyboards are viable except in highly specialized situations.</p>	<p>Aldon et al (1972) Seibert (1972)</p>
Lightpen, Lightgun	<p>Lightpens can be used effectively for cursor placement and text selection, command construction, and for interactive graphical dialogues in general, including drawing. However, there is evidence that greater accuracy may be possible with a mouse in discrete tasks, and with a trackball in drawing tasks. Mode mixing, as by alternating use of lightpen and keyboard, can significantly disrupt performance, since the lightpen must be picked up and replaced with each interval of use. Continuous use of a lightpen, at least on commercially available CRT terminals with vertical display surfaces, can be quite fatiguing. There has been no known research on desirable physical and logical properties for lightpens.</p>	<p>English et al (1967)** Goodwin (1975)** Irving et al (1976)** Ramsey (unpublished)**</p>
Joystick	<p>There are many studies of the use of joysticks for continuous tracking tasks, but few studies of its use for discrete or continuous command selection or graphical input tasks. Those studies which have been performed have found the mouse, lightpen, and trackball preferable in terms of speed, accuracy, or both. Joysticks are sometimes used for windowing and zooming control in graphical displays. No research on this topic was found, although the results of tracking studies may be applicable here. Otherwise, no clear recommendations for joystick properties emerged from the survey, even with respect to basic issues like position vs. rate vs. acceleration control. These issues may be fairly task specific.</p>	<p>Card et al (1977)** English et al (1967)** Irving et al (1976)**</p>
Trackball	<p>The trackball appears to be effective for both discrete and continuous command selection and graphical input tasks, and may yield the best performance when graphical inputs must be alternated with keyboard input. No empirical data on physical properties were found, but some such data are thought to exist in the tracking literature.</p>	<p>Irving et al (1976)**</p>

Table 6-2
Input Device Types (Page 1 of 3)
(From Ramsey, 1979)

Input Device	Comments	Principal References
Mouse	Although the mouse is not in widespread use, there is evidence that it is an effective device for text selection. No data are known concerning its physical properties, or its use in other tasks.	Card et al (1972)** Engelbart (1971) Englich et al (1967)**
Graphical Input Tablet	Graphical input tablets are capable of fairly high pointing accuracy (within 0.03 cm, according to one study). They are commonly used for freehand drawing, but may be inferior for discrete position input tasks. They may also involve a performance decrement due to low stimulus-response compatibility when the drawing surface is separate from the display surface.	Englich et al (1967)** Myer (1968)**
Touch panel	No empirical performance data were found dealing with the touch panel. While its inherent resolution limits may preclude serious use for fine discrete position and continuous position input, it feels "natural" and may become a common device for more coarse positioning and selection from lists.	Hladky (1969) Johnson (1977)
Voice control	A knee control has been used in one research study for discrete position input. It is not known to be in use otherwise, and seems unlikely to see serious use.	Englich et al (1967)**
Thumbwheels, switches, potentiometers	These have been studied primarily outside the computer systems domain, and are discussed in standard human factors reference sources. They are not often used as major user input devices for interactive computer systems.	Noll (1972)
Tactile Input devices	Although some tactile input devices have been proposed, little human factors research has been done other than that concerned with prosthetics.	Slack (1971) Ward et al (1967)**
Psychophysiological Input devices	Electromyographic signals have provided superior performance in some control tasks to joysticks and other manual control devices. Use of heart rate, biofeedback response latency, EEG input, etc., is technically feasible, although really sophisticated input is not yet achievable via these methods. There are ethical and legal problems here, as well as technological difficulties. Significant human factors data were not found with respect to computer-related use of these techniques.	

Input Device Types (Page 2 of 3)
(From Ramsey, 1979)

Input Devices	Comments	Principal References
Automated speech recognition	The current state of this technology limits its use to relatively simple input tasks. Even there, there are problems with different speakers, noise, etc. Although speech input seems like a very desirable and natural input mode, and is clearly preferred over other communication modes for interpersonal communication, it is not clear whether it will prove to be widely applicable for human-computer interaction tasks. Very little information was found which would assist the designer in recognizing tasks for which speech input is appropriate, or in selecting an appropriate speech input device.	Addis (1972)* Bazdel (1970)** Braunstein & Anderson (1959)** Chapanis (1975, 1976)* Turn (1974)
Hand printing for optical character recognition (as for subsequent entry by teletype)	The constrained hand printing required for OCR input results in low input rates, and sometimes high recognition error rates as well. Although manual transcription of such data clearly cannot be avoided in many cases, the preponderance of evidence suggests that direct keyboard entry yields better performance than printing, with a little practice, even when users are not skilled typists. Some error and input rate data on handwriting exist, along with some information about the effect of various printing constraints on input performance.	Avey (1976)** Bewne (1967)** Masterman & Hirsch (1962)** Smith (1967)** Strub (1971)**
Mark sensitive	As with hand printing, this separate transcription results in lower input rates than does practiced, but unskilled, typing. Some error and input rate data exist. May be slightly faster than constrained hand printing.	Devue (1967)** Fulp & Kulp (1977)** Nea (1977)**
Punch cards	Keypunching performance differs significantly from ordinary typing because of differences in both the machine and the typical data to be keyed. Some reasonably good data exist on keypunch timing and error rates.	
Touch-tone telephone	Several studies suggest that the touch-tone telephone is a satisfactory device for occasional use as a computer terminal, even by naive computer users. It seems clear, though, that it is not a satisfactory device for prolonged interaction or for significant amounts of nonnumeric input.	Miller (1974)** Smith & Goodwin (1970) Witten & Madams (1977)

Input Device Types (Concluded) (From Ramsey, 1979)

or generic input devices and tasks which are then controlled by the interactive software. Ramsey (1979) suggests that there are five major types of input tasks.

1. Text input
2. Numerical input
3. Command selection
4. Discrete position (graphical) input
5. Continuous position (graphical) input

Knowing what the input task is helps in the selection of the input device(s) which will be most useful, efficient and effective. If large amounts of text are to be input then an alphabetic keyboard is needed. Lightpens, trackballs, joysticks, and graphics tablets would be virtually useless. For limited typing, keypads or touch panels would be useful. Optical character recognition systems could be used to input full pages of text or handwritten documents. Research on optical character recognition done in the mid 1960's showed that input rates were slower than unskilled typing (Devoe, 1967; Masterson and Hirsch, 1962). However recent advances have made optical character recognition systems much more efficient and effective. Very little comparative research has been conducted on these new character recognition systems.

Numerical input would likely be most effective and efficient using touch tone keypads, numerical keypads, or voice recognition input.

Graphics positional input (either discrete or continuous) requires the use of a graphical input device. The lightpen, joystick, trackball, mouse, graphical input tablet or touch panel could be used. Selection of the best device depends on a thorough analysis of the task and environmental constraints.

Ramsey (1979) notes that there is a large body of research on input devices, but the majority of the research has been restricted to the computer keyboard as an input device. The research on other input devices is rather limited. The majority of such studies compare the speed and accuracy of only a few of the input devices on a specific research task. Although these studies do provide some general suggestions about the effectiveness of the alternative input devices, they do not allow for the preparation of specific guidelines for selecting and designing input devices.

Keyboard Research Development

Alden, Daniels and Kanariels (1972) suggest that the major human factor issues in keyboards are concerned with key dimensions (.5 inch diameter, .75 center to center spacing), key force and displacement (.9 to 5.3 oz force and .05 to .25 inch displacement), tactile feedback, keyboard size, numeric cluster arrangement and benefits of chorded rather than key by key sequential entry. Hanes (1975) and Cakir, Hart and Stewart, 1979, also provide excellent reviews of issues in keyboard design and use. Martin (1973) and Burch and Stratler (1974) discuss the benefits of special function keys.

Cakir, Hart and Stewart (1979) list the following parameters which affect the feel and useability of the keyboard.

PARAMETERS

SPECIFICATIONS

Shape and profile of key tops	Square shaped keys are preferred.
Keyboard profile	Keyboard angle should be 5 to 15 degrees
Keyboard thickness	30mm from base to home keyrow
Dimensions of Keys	Square keys 12-15mm center spacing 18-20mm
Size and coding of key legends	User programmable keys are beneficial
Key force and travel	Force 100-300 grams Displacement 4 to 8mm
Tactile feedback	Useful for inexperienced users
Key roll characteristics	Error rates 30% lower with rollover or chorded keys which store all key strokes
Color and reflection of key and keyboard surfaces	Glossy reflective keys cause less fatigue and headaches than matte finished keys. Grey or light colored keys are more effective than black or dark colored keys.

Keyboard Layout

The major factors which should be considered in the keyboard arrangement are as follows (Cakir, Hart and Stewart, 1979):

- operation of the keyboard should require as many changes from one hand to the other as possible.
- the letters in the home row of keys should include those which occur most frequently in the language.
- there should be a roughly even distribution of load between the right and left hands but with slight emphasis on the right hand.
- the distribution of load on the key rows should give emphasis to the home row, then to the top and bottom rows in that order.
- the least use should be made of the ring and little fingers, i.e. the keys at the ends of each row should correspond to the least frequently occurring letters in the language.
- the number of keying sequences requiring the consecutive use of the middle/ring and ring/little fingers should be kept to a minimum.

- wide and awkward spans of the fingers on each hand should be avoided or at least kept to a minimum.

Three major keyboard arrangements have been proposed: the standard QWERTY layout, the Dvorak keyboard, and the Meir keyboard (Cakir, Hart and Stewart, 1979). Kroemer (1972) also proposed an alternative keyboard design in which the keys are separated into two subkeyboards--one for each hand. The separate hand keyboards are at angles designed for ease of typing at normal arm levels. Although advantages are claimed for each of the keyboards, the standard QWERTY layout has survived and become the de facto standard for keyboards. The keyboard recommended for use in the Spacelab Data Display System includes the standard keyboard, three dedicated function keys, and 25 programmable function keys.

The major numeric key layouts are the touch tone arrangement and the adding machine layout. For inexperienced users the telephone layout is more effective.

The combination of a standard QWERTY keyboard with a function keypad is common. Programmable function keys permit the same key to call forth different functions in different programs; this can significantly extend the usefulness of the function keypad.

Hand Held Keypads and Keyboards

Hand Held keypads are very frequently used in hand calculators, remote controls (TV), and electronic games. Business and industry have started to use hand held terminals for point of sales use. Recent videodisc players also use hand held control units for videodisc control. In addition, WICAT has developed a keypad for controlling an interactive videodisc system. A recent issue of BYTE (January 1981) had a special report on hand held computers. Figure 6-8 presents a typical hand held computer.

New Keyboard and Key Developments

Recent use of hardened plastic membrane switches and plastic keys allow for the preparation of membrane keyboards with the feel of spring loaded keys. The cost for OEM quantities will be \$20-\$30 for a 59 key keyboard (Ohr, 1980).

Solid State Technology recently announced the sale of a Proteus terminal. Like the Greek god namesake, the terminal enables a user to modify the form of the input device to match any occasion. Instead of a standard keyboard the user develops customized keyboard layouts whenever needed. The newly designed keyboard layout can be activated through a touch sensitive overlay panel for a CRT screen. "Programmers can arbitrarily assign any meaning to any symbol making a character stand for a whole instruction set, a subroutine, or a program. (Lowe, 1980)." New keyboards can be designed in about five minutes, it is claimed.

Voice Input

Voice input is especially useful where hand or eyes are busy. An example is a maintenance aiding task, where the soldier can ask verbally for a new page of a technical manual to be presented or for other information. Speech is a natural means of communications for untrained soldiers who cannot type. High quality voice input units are more accurate than typing, although there is a wide range of recognition accuracy available in the marketplace. Voice input also permits greater mobility than a keyboard. For example, the voice input system can use a radio to transmit over short distances, thereby freeing the soldier from distracting and annoying wires leading back to the voice input unit.

There is a wide range of voice input recognition accuracy and cost. The price ranges from a few hundred dollars to well over sixty thousand dollars for individual units. These cost differences are primarily related to two factors: The first is recognition accuracy and the second is the ability to distinguish words separated by very brief pauses.

After reviewing many commercial systems, discussing capabilities of voice input systems with current users, and reviewing the literature (see for example, Lea, 1980 or Levinson and Liberman, 1981) we have concluded that the majority of current voice input systems are virtually useless for most military applications because of their limited recognition accuracy. Units with sufficient accuracy for widespread use typically cost more than seventy-five hundred dollars today.

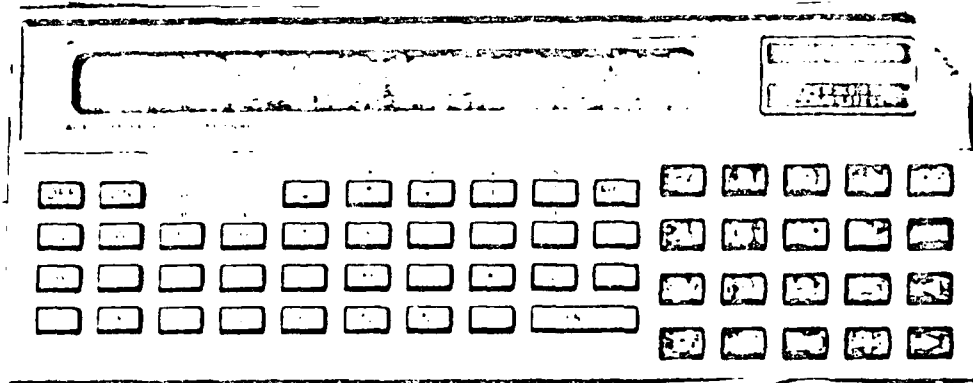


Figure 6-8. A typical hand held computer.

It should be noted that recognition accuracy bears little resemblance to the published reports of the manufacturers. One must see the units in action or talk with knowledgeable users to gain a true picture of how the system performs in the field.

The other major determinant of cost is the ability to recognize words which are separated by very short pauses. In our normal speech, words are seldom separated by pauses. Instead, we speak in an almost continuous string, which others can understand only because they are able to use many cues and expectations to decipher the word string. For example, when we say, "I made a deposit at the _____" we can fill in a number of plausible words, and even rank them in order of likelihood. Without this ability to use non-verbal cues and expectations based upon what is being said, voice recognition systems are at a great disadvantage in relation to human listeners.

The problem of separating words is further complicated by the fact that many silences occur within individual words. It is not uncommon to find a silence of 90-100 milliseconds within a word, but a much shorter pause, if any, between words. For this reason most voice input systems are limited to recognizing isolated words. "Isolated" is defined as a pause of greater than approximately 120 milliseconds. In essence, words must be spoken one at a time.

A few of the more expensive systems now permit connected speech recognition. In this system, the pause between words can be shortened considerably, and can even be less than the 90 to 100 millisecond silences found within words. In order to accomplish this, the voice recognition system must try to match words at every silence. Since it cannot know whether the silence is within a word or between words, the system must compare the words which it expects against each portion of the speech string, and must attempt different combinations of the speech sounds which are separated by short silences in order to try to find a match. This requires considerable processing power.

Ultimately a system to recognize continuous (normal) speech will be designed and built. Such a system will almost certainly need to "understand" what it is hearing. This capability has been pursued for decades, and still appears to be years away from a commercial realization.

The majority of current voice recognition systems are speaker dependent. This means that each user of the system must train it for every word that is to be recognized. The training usually consists of ten repetitions of the word or other utterance. Utterances can be up to two to three seconds each. This permits recognition of short phrases up to three or four words in length which will always be treated as a unit. A few systems have been designed to be speaker independent. These systems are usually very expensive and quite limited in the number of words which they will recognize. Speaker dependent

systems will recognize between approximately forty and three hundred words, depending upon options.

In sum, the voice recognition system most likely to be feasible for Army use in 1985 is a high quality, speaker dependent, isolated or connected word unit. This type of unit is commonly used today for voice controlled numerical machine programming, for sorting packages at shipping docks, and for quality control inspections. In the Army it can be used for these applications as well as for simulations of voice-dependent operator tasks and for maintenance aiding.

CHAPTER 7

DISPLAY DEVICES FOR ELECTRONIC DELIVERY SYSTEMS

Output devices are computer peripheral devices which display alphanumeric, graphical or realistic visual information from interactive systems. The three major classifications of output devices presented below will be considered in this chapter.

1. Teletypewriters, printers and word processors which provide hard copy output.
2. Cathode ray tubes (CRT's) which present alphanumeric and visual information on any of a variety of television-like terminals.
3. Flat panel displays which present alphanumeric and/or visual information on any of a variety of flat panel electronic display devices.

A fourth type of output device concerns two and three dimensional output devices such as dial and gauge control, turtles and robots. Since the majority of work in instruction and training involves the first three types of output devices, the research and recommendations presented in this chapter concern the first three categories.

Subdivisions within each major category will discuss the various types of electronic output devices within each general family. Comparative evaluation information among the display alternatives, if any, will be presented and current and future trends in technology will be noted. A brief preview of some of the subsection topics might be helpful.

The section on teletypewriter printers will discuss word processing printers, computer line printers, office printers of various types and low cost printers. The types of printers include impact printers (which use fully formed characters) and dot matrix characters, ink jet printers, thermal printers, dielectric printers and photographic laser printers. The section on CRT displays will discuss refreshed and storage CRT's, vector CRT's, raster scan CRT's (television), and digital TV CRT's. The section on flat panel displays will discuss flat CRT's, light emitting diodes (LED's), electroluminescent film displays, gas discharge plasma panels, liquid crystal displays (LCD's) and electrochromic and electrophoretic (EPID) displays.

Teletypewriter Printers

Teletypewriter printers provide hard copy paper based output from interactive computer and word processing systems. Word processing systems vary from the highly sophisticated specialized word processing systems (e.g., Xerox, Wang, Lexitron) to word processing packages for main frame computers, minicomputers and microcomputers. Excellent reference sources indicating the variety and cost of various word processing units are available (Datapro, 1980;

Mandell, 1980; Snyders, 1980). The prices range from \$100,000 for complete word processing systems, to \$4,000 for word processing packages, to \$20 for single desktop word processing programs. Two major types of printers are available: fully formed character printers and dot matrix characters. Fully formed characters are similar in quality to IBM Selectric typewriter print. The speed of the fully formed character printers is 40 to 60 characters per second for the Qume, Diablo and NEC and recent IBM daisy wheel printers. The dot matrix printers produce lower quality output but at higher speeds. Electronic data processing printers using dot matrix output can print at speeds of 120-600 characters per second. High speed line printers are available which will print 900-1200 characters per second, 400 to 600 lines per minute. High speed line printers are primarily used for centralized computer printers.

The above discussion has been focused on impact printers. Other printer alternatives are available using thermal, ink jet, dielectric and photographic lasers as printing devices. Of these alternatives the laser printer appears to offer the most promise for non-impact printers (Iverson, 1981). Laser printers are expected to capture more than half of the market for non-impact printers.

Following are some specifications for recently developed laser printers. Hewlett Packard has developed a laser printer which prints 15 pages per minute with a cost of \$108,500. Xerox has developed a laser printer with speeds of 43 pages per minute (\$91,500) and AM International has produced a laser printer with a speed of 70 pages per minute. Dale Kutnick indicates that, "By 1983 or 1984 we'll see a lot of (laser printer) units under \$20,000. We'll even see some slower units (12 to 20 pages per minute) at the \$10,000 to \$15,000 level." (Iverson, 1980). Since the laser printers are designed to print digitally coded computer characters they can easily be linked up in network configurations to provide electronic mail functions.

The Ricoh Company recently introduced an integrated system which consists of three units: a word processor, a 30 page per minute laser printer, and a digital image scanner and processor. Edgor Gladstone (1981) notes that the Ricoh system provides the capability "to scan any kind of document into memory," and transfer the document or image across high speed lines to a remote laser printer.

AM International has demonstrated a laser scanner printer system which scans and prints documents at 30 pages per minute. The information is compressed and digitized for storage on a magnetic disk. The stored document can be transmitted at speeds as high as 1 megabit per second. At the receiving end the laser printer prints the document at 70 pages per minute. Copies at several different sites can be made concurrently. Presently, the fastest facsimile printer takes from 30 to 40 seconds to transmit one page to a single location.

Colored hard copy output is also possible through several alternative approaches. Photographic processes developed by Dunn Instruments, Matrix instruments, Image Resources and Polaroid accept RGB video input from a CRT screen and use a series of color filters to expose a photographic film in accord with the color pattern information from the RGB signal. The

photographic systems provide very high resolution, sharp bright colors, and ability to produce 35 millimeter slides or 8½ x 11 inch transparencies. Optronics International has produced a laser scanner printer system in which the color image is digitized, stored and produced. The system is primarily used for aerial photography, radiographs and geophysics. Resolutions of the color laser printer are 1000 to 2000 lines per inch with a price tag of \$65,000 to \$100,000. Color laser copy systems have also been introduced by the Xerox company. The copier uses a laser beam to write on a photosensitive drum. The sensitized parts of the drum pick up colored toners and then transfer the colors to a sheet of paper or transparency film. The color Xerox system sells for \$28,000.

Cathode Ray Tube (CRT)

The cathode ray tube is the most common device for electronic information and visual delivery. A familiar type of the cathode ray tube is the standard television receiver or monitor. CRT's can be divided into four major classifications for this report.

1. Raster refreshed CRT's
2. Vector CRT's
3. Storage CRT's
4. Digital Television CRT's

Raster refreshed CRT's are the common types of television monitors and computer terminals which require continuous refreshing of the visual display to maintain a flicker free image. Raster refreshed CRT's are generally defined by the number of scan lines per frame (525 scan lines is the standard for NTSC color and black and white television, 625 scan lines is the standard for European PAL and SECAM television systems.) Low, medium and high resolution systems are currently available for both monochrome and color TV systems. Low resolution systems are generally classed from 200 to 500-525 scan lines. Medium resolution systems offer 600 to 800 scan lines and high resolution systems offer 800 to 1200 scan lines.

Vector CRT's use random vector patterns rather than a fixed horizontal scanning pattern to construct an electronic-based visual image. Storage CRT's, as the name indicates, have a memory device which maintains the visual image on the screen without continuous refreshing of the screen. Excellent references on CRT devices are Sherr (1979), Cakir, Hart and Stewart (1980); Luxenberg and Kuehn, 1968, and Herold, 1974. Summary specifications for various CRT devices are presented in Tables 7-1, adapted from Sherr (1979) and 7-2, from Bean (in press).

Table 7-1

COMPARISON OF PARAMETERS FOR VARIOUS CRT DISPLAYS
(Sherr, 1979)

	<u>Luminance</u>	<u>Bandwidth</u>	<u>Resolution</u>	<u>Display Size</u>
Raster CRT				
Monochrome				
Standard	120-300nits	4-10MHz	480 lines	20-60cm
High Resolution	120-300nits	10-30MHz	1000 lines	30-60cm
Color				
Standard	150-250nits	5-10MHz	600H 450V	50-60cm
High Resolution	150-250nits	22MHz	1200H 900V	33-48cm
Digital				
Standard	300nits	10MHz	512x512pix.	varies
High Resolution	300nits	30MHz	880x1024pix.	varies
Vector CRT	300nits	15MHz- 35MHz	1000 lines	40-53cm
Storage CRT				
Electrical	to 150nits	30MHz	1400 lines	varies
Directview	30nits	--	400-800 lines	50-63cm
Electrostatic	150-500nits	25MHz		28x38cm

Table 7-2

SUMMARY CHARACTERISTICS OF ELECTRONIC DISPLAYS
(Adapted from Bean, in press)

	1	2	3	4	5	6
	MAXIMUM	AVERAGE		GRAY		
<u>DISPLAY</u>	<u>BRIGHTNESS</u>	<u>BRIGHTNESS</u>	<u>CONTRAST</u>	<u>SCALE</u>	<u>COLOR</u>	<u>SYMBOL</u>
	<u>(f1)</u>	<u>(f1)</u>	<u>RATIO</u>	<u>LEVEL</u>		<u>TYPE</u>
CRTs						
Raster	1000-2000	500-2000	50:1	12	G	Raster
Color		100-200	32:1	10	R,G,B	Raster
Random Vector	10,000	500-2000	50:1	12	G	Stroke
Storage		1000	50:1	(12)	G	Stroke
Display	500	30	32:1	8	G	Matrix

Table 7-2

SUMMARY CHARACTERISTICS OF ELECTRONIC DISPLAYS (CONTINUED)

	7	8	9	10	11	12
<u>DISPLAY</u>	<u>STORAGE</u> <u>(+PRESENT,</u> <u>-ABSENT)</u>	<u>FLAT</u> <u>PANEL</u> <u>(+yes,</u> <u>-no)</u>	<u>RESOLUTION</u> <u>ELEMENTS/</u> <u>INCH</u>	<u>ELEMENTS</u> <u>PER</u> <u>DISPLAY</u>	<u>DISPLAY</u> <u>SIZES</u>	<u>HOW MANY</u> <u>CHAR. PER</u> <u>FRAME (FULL</u> <u>SCREEN) MAY</u> <u>BE DISPLAYED</u>
CRTs						
Raster	-	-	100	512x512, 1024,1024 (4096,4096)	5"x7", to 32"	to 3000
Color	-	-	20	512x512	5"x7", to 25"	3000
Vector	-	-	100+	512x512, (4096x4096)	5"x7"	3000
Storage	+	-	80	512x512,	5" round	3000
Digisplay	-	-	55-80	512x512	6.4"x6.4", 5"x10"	1920

	13	14	15
<u>DISPLAY</u>	<u>CAN DIAGRAMS, SCHE-</u> <u>MATICS OR PICTORIAL</u> <u>DATA BE PRESENTED?</u>	<u>BEST AMBIENT</u> <u>ILLUMINATION?</u>	<u>OPERATING CONDITIONS</u> <u>BEST</u> <u>FEATURES?</u> <u>WORST</u> <u>FEATURES?</u>
CRTs			
Raster	+ yes-video image	- low-mid	CRT's have high resolution, brightness, low cost, color
Color	+ yes-color video image	- low-mid	CRT's are relatively bulky, less - portable, require high voltage, have screen curvature
Vector	+ yes-high resolu- tion		
Storage	+ yes		
Digisplay	+ yes		

These tables show that the luminance for CRT's is generally from 120 to 300 nits (cd/m^2). The video bandwidth for standard raster CRT's is from 4 to 10 MHz while high resolution requires a bandwidth of 10 to 30 MHz. Vector and storage CRT's also require a bandwidth of 15-30 MHz. Higher bandwidths are needed for faster character and scanning of information. The resolution of standard CRT's is between 480 and 600 lines while high resolution CRT systems

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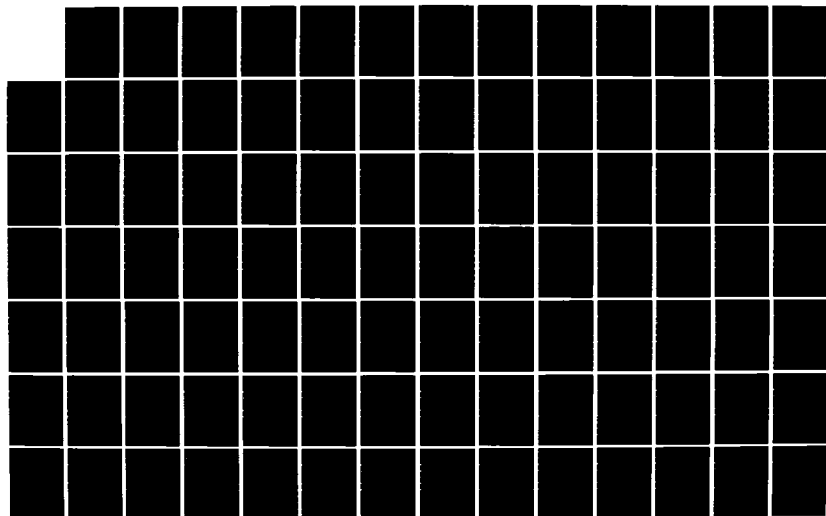
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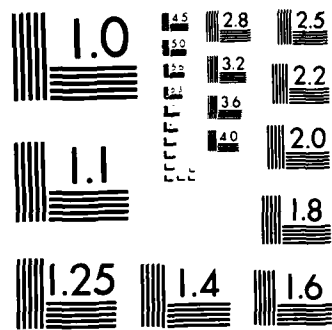
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MICROCOPY RESOLUTION TEST CHART
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range from 900 to 1000 lines. Bean notes that displays of 4096 x 4096 pixels are possible. Contrast ratios for CRT's are from 32 to 1 to 50 to 1. Between three and four thousand characters are possible per frame on some CRT displays.

A review of recent electronic journals yielded the following Table 7-3 of high resolution capabilities.

Table 7-3

COMPARISON OF HIGH RESOLUTION MONITOR CAPABILITIES

<u>Company</u>	<u>Pixels</u>
Aydin	1024 x 1024
Conrac	1280 x 1024
Genisco	
Hitachi	1280 x 960
DEC	1024 x 1024
Lexidata	1280 x 1024
Magetek	1024 x 1024
Magetek	1280 x 1280
Magetek	4096 x 4096
Sanders	1024 x 1024
Tektronix	4096 x 3120
Hewlett Packard	1000 x 1000
Chromatics	512 x 512
Ramtek	1024 x 1024
Chromatics	1024 x 1024
Amperex	1500 scan lines

Classification of CRT Terminals

CRT devices can also be classified in terms of the processing and graphic capabilities of the CRT. This section will follow the classification of non-intelligent terminals, smart terminals, intelligent terminals, stand alone systems, and graphic terminals. The capabilities of each terminal are discussed by Warren (1980). Non-intelligent terminals are serial input CRT's or teletypewriter replacements. The terminals include a keyboard and CRT screen but no microprocessors or local memory is provided. Smart terminals provide vendor rather than user programmability, editing and screen function keys, small local memory, and costs of between \$400 and \$3,000. Intelligent terminals include CPU's from 8 bits to 32 bits, user programmability, sophisticated operating systems, and high level language capability, larger local memory up to 16k bytes or more, supporting peripherals without reliance on the host computer, and prices from \$1,000 to several thousand dollars. Stand alone systems provide all of the capabilities of intelligent terminals but have stand alone processing, storage, and input devices in addition to text displays.

Television Standards

This section discusses the three current worldwide standards for television systems. Following sections discuss future technological developments in digital television and high definition (resolution) television.

Three major worldwide standards are employed in television systems. The U.S. follows the National Television System Committee Standard of 525 scan lines, 2:1 interlace ratio with 30Hz per visual frame and 60Hz for each visual field (half a frame). A composite video signal is employed to code for the luminance (brightness) component and the chrominance (color hue and saturation) component. The luminance component is formed by specified proportions of the red (R), green (G), and blue (B) signals. The chrominance component uses a set of color differences (R-Y, G-Y, and B-Y where Y is the luminance component calculated above).

The Phase Alternation Line (PAL) system used in the United Kingdom, Europe and Brazil employs 625 scan line, 2:1 interlace ratio with 50Hz per frame. The phase of the color signal R-Y, is reversed 180 degrees on alternating lines, leading to the name phase alternation line system. The SECAM system is used by France and Russia. The SECAM is a 625 scan line system 2:1 interlace ratio 50Hz per field.

Table 7-4 presents the major comparison information for these three television systems.

Table 7-4

COMPARISON OF TELEVISION SIGNAL STANDARDS

	<u>NTSC</u>	<u>PAL</u>	<u>SECAM</u>
Field Rate	60	50	50
TV Lines	525	625	625
Video Bandwidth (MHz)	4.2	5.0-5.5	6.0
Sound Bandwidth (MHz)	4.5	5.0-5.6	6.5
Interlace Ratio	2:1	2:1	2:1

This table highlights that standard television systems have 525 or 625 scan lines and require a video bandwidth of 4 to 6MHz for transmission and reception. For additional information on television specifications the reader is referred to the following references: Pritchard and Gibson, 1980; Fink, 1955; Herbstreit and Pouliquen, 1967; and Roizen, 1967.

Digital Television

Standard television signals are electronic signals coding for a real visual scene. Digital television converts the analog signals to digital signals at the television camera level. The digital signals are processed at the television transmission station. Digital signals are received at the receiver or monitor and converted from digital to analog signals for viewing of the visual scene.

Digital TV has several major advantages. The digital signal is much more robust than the analog signal. Digital signals can be recorded and rerecorded multiple times and still retain their full character quality. Digital signals offer the possibility of worldwide standardization of television standards, digital signals provide for higher resolution levels at camera, transmission, and receiving units, and digital TV provides the possibility of high quality large screen displays.

Digital TV Components

Recent developments in television electronics have provided for the use of complete digital systems for television transmission and reception. Numerous digital TV cameras have been developed (Nagumo, Asaida and Ochi, 1980; Miyaji, Morita and Nishizawa, 1980). Digital video recorders have been developed (Morizondo, Yoshida and Hoshimoto, 1980; Diermann, 1978; Baldwin, 1978; Nasse, 1980; Yokayama, Nakagawa and Kalayma, 1980; Moore, 1978; Raigner and Ratleff, 1979). Digital to analog converters are available (Kester, 1979; Nasataka, Harada, Uehara, 1979; Bucklen, 1980 and Webster, 1980). Digital television coding and transmission systems have been developed (Brown, O'Brien, Sawchub, Storey and Marsh, 1980; Connor, 1980; Ishiguro, Tomozawa and Mune, 1980; Raigner and Ratleff, 1979; Burkies, and Wade, 1980; Forster and Sochor, 1980). Digital transmission using fiber optics has been demonstrated (Goldberg, Jachnowyeg and Rossi, 1979; Maney, 1980; Rozien, 1980; Connor, 1980; Potter, 1980; and Proceedings of IEEE, 1980). Digital television systems have been discussed and demonstrated (Sherr, 1979; Anderson, 1979; Anderson, 1980; Ishiguro, Tomozawa and Mune, 1980; Limb and Bowen, 1980; Raigner and Ratleff, 1980; Rozien, 1980).

The above developments provide for all-digital TV implementation within the next 5-10 years. Major TV broadcasting studios will steadily convert their analog equipment to digital equipment. In the interim period the studios will be using a combination of analog and digital equipment.

Digital TV Requirements

Digital TV requires higher bandwidth and bit transmission rates than standard analog TV systems. See Table 7-5.

Table 7-5

LINE AND BANDWIDTH STANDARDS

Line Rate	525	951	1225	1351	1601
Bandwidth					
NTSC MHz	4.2	15	20	28	40
PAL MHz	5.5	22	30	42	60

Isozaki (1978) indicates need for 30MHz for a 1600 line system. Burkhard and Wasser (1980) indicate 22MHz for 34Mbit/s digital transmission rate. Fink (1980 a, b, c, recommends 25 MHz bandwidth for digital TV systems of the future with 1100 scan line rate. Forster and Sochor (1980) recommend 50MHz for digital recording systems at 80Mbits/second recording rates.

All references above indicate the need for increases in the standard television bandwidth spectrum. As the expected line rate increases so does the necessary bandwidth. Bandwidths of 15 to 30 MHz are needed for television scan line resolutions of 900 to 1225 scan lines. Bandwidths of 20 to 60MHz are necessary for line rates of 1350 to 1600 lines.

Transmission and recording bit rates need to be increased for digital television. Transmission bit rates of 80 to 114M bits/second are needed for full digital transmission (Burkhardt and Wasser, 1980, Connor, 1980, Ragner and Ratleff, 1980, Forester and Sochor, 1980).

Digital recording bit rates of 80 to 160 Mbits/second are needed for full digital recording depending on the tape size and speed (Nasse, 1980; Burkhardt and Wasser, 1980; Yokoyama, Nakagawa and Kalayma, 1980). Bit rate reduction schemes can be used to lower the overall digital transmission and recording rates. Interframe coding schemes can reduce the required bit rate to one-third of the full bit rate (20-35Mbits/sec.) (Limb and Bowen, 1980; Nasse, 1980; Ishiguro, Tomozawa and Mune, 1980; Raigier and Ratleff, 1979). Picture Description Instructions can greatly reduce the transmission rate (Brown, O'Brien, Sawchuk, Storey, and March, 1980).

High Definition Television

The Society of Motion Picture and Television Engineers (SMPTE) has formed an ongoing study group to outline the potential technologies for high definition television. The following are the major recommendations from the group of 14 major TV engineers headed by Donald G. Fink who played an important role in the two NTSC committees which developed the U.S. television standards. Donald Fink provides the following major recommendations. (Fink, 1980)

1. The approximate line rate for High Definition TV (HDTV) is 1100 lines per frame, with 1500 lines per frame as a future objective.
2. The frame rate should be 30 per second, interlaced two to one for all applications, except the production of motion picture release prints, for which the rate should be 24 per second without interlacing (progressive scanning), with

standards conversion to interlaced scanning introduced for direct observation during production.

3. The aspect ratio should be not less than 5:3 and preferably 2:1.
4. The technique of employing a chrominance subcarrier located within the luminance band should not be used.
5. Separate transmission or time division multiplexing should be used for the transmission of chrominance information.
6. The luminance bandwidth (for an 1100 line-per-frame raster) should be approximately 25MHz, the precise value depending on the aspect ratio and horizontal retrace time.

"One of the major premises of the study was that any HDTV must be capable, after suitable standards conversion, of being received on domestic color television receivers of current design (i.e., those served by NTSC, PAL, or SECAM transmissions) and that the quality of reception must not be inferior to that inherent in the design of the receivers. Also a large screen, wide aspect ratio (5:3 or 2:1) was needed. A home screen display 2m x 1m (80 inches x 40 inches) is a typical objective", (Fink, 1980).

Present HDTV systems may require higher line rate and higher luminance and chrominance bandwidth than the NTSC standards. The aspect ratio must be higher than the NTSC standard of 4:3 and the viewing distance needs to be less (2.5 times picture height) than the corresponding NTSC value (about four or five times the picture height). Most importantly, the method of chrominance multiplexing must employ methods different from, and having greater effective bandwidth than, those of the NTSC system. Standards conversion from HDTV to NTSC, PAL, and SECAM systems is possible.

Teletext and Viewdata

Teletext and Viewdata are electronic communication methods whereby text and graphics are either broadcast in unused television scan lines (Teletext) or are transmitted over telephone lines using modem connections (Viewdata) (J. Jackson, 1980; Clarke, 1980; Crowther, 1980; Chambers, 1980; Hedger, Raggett and Worburton, 1980; Brown, O'Brien, Sauchuk, Storey and March, 1980; Clarke, 1980). The Teletext system digitizes magazines through unused television scan lines. The scan lines used are outside the picture area and remain unseen by the viewer. With a special teletext decoder the digitized pages can be converted to analog signals and displayed on the television receiver. The magazines are broadcast in continuous fashion and can be modified, updated and rebroadcast at the television station. The person subscribing to a teletext system could have ready access to up to 8 independent magazines of up to 320,000 teletext pages of 24 lines of 40 characters of information. Four pages of teletext can be transmitted each second. Although the capabilities are very high as noted above, generally a magazine of teletext will consist of 100 pages and requires 24 seconds for each complete cycle from page 1 to page 100. Using the decoder the viewer could also request continuous access to specified pages or topics of interest (e.g. continuous record of U.S. stock exchange prices). Teletext can be

presented in up to seven different colors. Simplified graphics capabilities are provided through a 2x3 dot matrix for each character. This provides an 80 x 72 pixel grid for graphics, diagrams, bar charts and maps. The teletext decoders require four LSI circuits and two memory chips.

Viewdata is similar to Teletext except that it is transferred over telephone lines and it is interactive. Viewdata provides a much wider access to database information and more user options for selection of information. Using Viewdata the viewer transmits a request for information to a central computer or data base. The request signals are sent at 75 bits/second over telephone lines using modems. The viewer keys in the requested page(s) of information and the page(s) is sent to the receiver at 1200 bits second. Using Viewdata a full page of 960 characters is transmitted in eight seconds. Interactive work with the computer can be either through the use of tree structured menus or full keyboard selection of information topics. With the use of voice recognition systems available in the near future, the request for viewdata could be made in English. Viewdata can be used for information search and retrieval, computer-assisted learning, vocational training, self assessment programs, interactive educational programs, learning games and simulations and for data base management and reporting. Hedger, Raggett and Worbuton, (1980) discuss the potential capabilities of value added teletext for the distribution of interactive computer programs and educational programs using the various software. The Teletext or Viewdata receivers will likely become standard equipment on new television receivers.

Future Advances in Teletext and Viewdata

Philips Research Laboratories have made experimental Viewdata terminals that store up to four pages in RAM memory, and a cassette recorder that will store up to 300 Teletext pages on a 60-minute audio cassette (Jackson, 1980). Philips is also increasing the character grid for Teletext and Viewdata systems to 240 x 240 pixels. The Tehidon system used in Canada also provides for 240 x 320 pixels plus color and grey scale levels for each page (Jackson, 1980; Brown, O'Brien, Sawihuk, Storey and Marsh, 1980).

Following is a list of the major international organizations which are developing standards for videotext systems:

- European Broadcasting Union
- European Economic Community
- International Telephone and Telegraph
- International Radio Consultative Committee
- European Computer Manufacturers Association
- European Posts and Telecoms Administration
- International Standards Organization
- International Electronic Commission

Teletext and Viewdata are developing dynamically redefinable character sets (DROS) (Lambert, Brusq, Marti and Poignet, 1980) and picture coding instructions (Brown, O'Brien Sawchuk, Store and Marsh, 1980) which will provide for increased graphic capability and increased resolution of Teletext and Viewdata.

Ishigaki, Okada, Hashimoto and Ishikawa (1980) discuss several possible improvements in television design for better teletext reception.

Picture in a Picture TV

Multipicture TV sets and adjustable screen size TV's have been developed. Toshiba has developed a MultiWide system which provides for the display of one to four pictures at the same time. Sharp has developed a Multivision screen that permits simultaneous display of two to nine pictures. See Figure 7-1. Sanyo has developed an adjustable screen size television that permits three adjustments of screen size. Hewlett Packard has prepared a four window classification for data display terminals. This system provides for division of the display memory and display screen into four independent window and work area spaces.

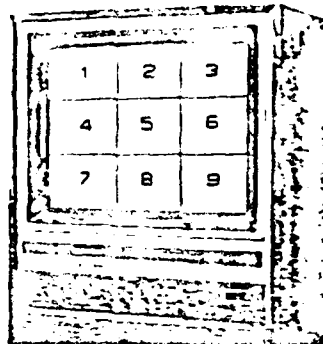


Figure 7-1

Multivision television set (Sharp Corp.)

Hitachi has developed a fully digitalized color picture within a picture television system presented in Figure 7-2.



Figure 7-2

Picture in Picture TV (Hitachi)

For additional information on multipicture TV displays see Masuda, Kuroyama, Imalde, and Nabeyama (1979), Burkhardt and Wasser (1980), and Allrich and Hegendorfer (1977).

Flat Panel Devices

In the past decade there has been considerable research and development work on solid state flat panel electronic displays. The flat panel displays offer smaller size, more ruggedness, lower power consumption and as high or higher resolution than previous CRT electronic displays. Costs of the flat panel devices are also dropping and will continue to do so for several years. This chapter will outline the various flat panel technologies and the general comparative findings across flat panel devices.

The major types of flat panel devices include flat CRT's (Digisplay), light emitting diodes (LED's), electroluminescent (EL) displays, gas discharge plasma panels, liquid crystal (LC) displays, electrolytic liquids, electrochromic displays, and electrophoretic (EPID) displays. Excellent references for flatpanel technologies are Sherr (1979) and Snyder (1980).

Flat panel CRT's can replicate regular CRT displays but are only 5-7 cm in depth as contrasted with regular CRT depth.

Light emitting diodes are used as small alphanumeric display devices for hand calculators, watches, and electronic displays. LED's are commercially available in four colors: red, orange, yellow and green. Sherr (1979) and Snyder (1980) note that LED's are useful for single and multiple alphanumeric displays but due to the high power consumption, large matrix and large screen displays will require future technologies.

Electroluminescence displays consist of a thin film layer of zinc sulfide, phosphors and copper (Cu) or manganese (Mn) activators which is placed in a dielectric medium between two electrodes carrying either AC or DC current of 30-650 volts. The application of voltage leads to emission of light energy which can be modulated. Matsushita Electric, Sharp Electronics and Westinghouse all have demonstrated the use of electroluminescent devices to present a monochrome commercial TV program. Electroluminescent displays have good luminance and gray scale, size, and high element densities (Snyder, 1980; Kazan, 1976). Allen (1980) notes that "of all the display technologies competing for application in large flat panels, none looks more promising than ac thin film electroluminescent technology." Elliot Schlam (1980), notes that ac thin film electroluminescent film shows the greatest promise for meeting the Army's tactical display requirements.

"Over the past 12 years, we've evaluated LED, LCD, plasmapanel, electrochromic, electrophoretic, and CRT displays, and evidence points to the conclusion that thin-film technology has the best future potential for the preponderance of our military panel objectives of highly mobile rugged displays."

Plasma or gas discharge displays are based on the same chemical principles as the NIXIE numeric indicator for neon lights and signs. Plasma panels involve a gas filled area through which an electrical field can be applied. The electrical field causes the movement of electrons from a high energy level to a low energy level. When sufficient number of atoms have lost at least one electron, the gas ionizes and emits light. Plasma panels can be used for large screen high resolution and TV video display devices.

The liquid crystal display is formed by sandwiching a liquid crystal substance between transparent glass plates. The application of voltage causes the realignment and movement of the liquid crystal molecules which modulates the light reflected from the liquid crystal substance. LC displays are widely used in watches and calculators.

New LCD applications include displays for marine applications, point-of-sale terminals, word processors, hand-held light meters for photography, digital panel meters, and medical instrumentation. Looking on the horizon are automotive, avionic, and agrionic (tractors, farm implements, and so on) applications, which several LCD manufacturers are working on penetrating. (Allen, 1980)

The LC display has a very low power requirement, which is comparable with the low power MOS (metal oxide semiconductor) technologies so that devices having LC displays could operate for extremely long periods on batteries.

The electrophoretic display is based on the principle of electrophoresis: the movement of charged particles in a liquid base as the result of the application of electrical field. The charged particles are of a different color and density than the surrounding liquid. Thus the electrophoretic movement of the charged particles to the display surface causes the observer to see the particles. When the field is reversed, the particles migrate away from the display surface and only the liquid can be seen. Electrophoretic principles in displays was initiated by Ota, Ohnishi and Yoshiyama (1973).

EPID's have been fabricated in sizes of 300 x 150mm. with pixel density of 5 elements/mm. and with color combinations of black/white, blue/white, black/yellow and red/yellow (Snyder, 1980). Lewis (1976) indicates that EPID devices may retain an image for several months after the electrical field is removed. Snyder (1980) notes that because of the slow response speed EPIDs will likely not be applicable for dynamic graphics and television displays.

CHAPTER 8

COST/BENEFITS ANALYSIS

This chapter presents the method for estimating costs, then for each system type presents a full feature configuration with options. In most cases one or more lower cost configurations are also presented and the tradeoffs are presented qualitatively.

The costs presented here are very rough, and are intended only to provide discussion points. The ACTO Data Base Correlation study will use these figures and the reviews of them to develop more definitive projections.

Cost Methodology

The following steps were necessary to cost the system types:

1. Identification of essential system components. This step was necessary because over the forecasting horizon the cost of each component will behave differently. Certain components are mature products and will remain constant in price or experience only moderate price decreases in real dollars. Other products are in the "take-off" stage and will experience sharp price decreases.
2. Determination of present shipments and estimated future shipments of each component. Most of these figures are estimates by industry experts and market research bodies (e.g., Data Pro). This is the primary factor in determining the magnitude of the cost decreases.
3. Position components on life cycle curve. This is a qualitative procedure that aids in the assessment of costs. Generally, as cumulative shipments double, the price falls 20 to 30 percent.
4. Determination of current costs. This was accomplished by obtaining price lists from manufacturers and distributors and interviewing marketing and engineering personnel. Since most sales transactions involve substantially fewer quantities than Army transactions, estimates were made of costs in terms of 5000 quantity transactions. Table 8-1 presents this data.
5. Determination of optimistic and pessimistic cost projections. Steps 2 and 3 led to a determination of estimates of the percent decrease in cost per year for each component. Sometimes two estimates of cost decreases were determined to indicate a probable range within which the true value would be expected to fall. One estimate represents a pessimistic or small percentage decrease in cost per year; the second estimate represents an optimistic or large percentage decrease.

Table 8-1

CURRENT AND PROJECTED COMPONENT PRICES
In Volume of 5,000 Units **

(All prices are in real 1981 dollars--must be corrected for inflation)

	Price in 1981	Projected Percent Decrease per Year to 1985 and 1985 Price						Expected price in 1985
		1%	5%	10%	15%	20%	25%	
INPUT DEVICES								
Keyboard	\$ 17	16	14					\$ 15
Keyboard	80	77	65					70
Low resolution joystick	28	31	34					25
Low resolution mouse	55	61	62					50
Touch panel	122					50		50
Validation (e.g., thermostat)	22	21	18					20
Trackball (low resolution)	150							150
OUTPUT DEVICES								
High resolution Voice Input	8000							850
High resolution graphics tablet	1100				575	450		450
High resolution joystick	370				190	150		150
High resolution Trackball	730				380	300		300
PERIPHERALS								
6 bit 8Kw ckr w/power supply, etc.	3000						36%	520
6 bit commercial processor	1000						32%	210
6 bit (technology) of RAM (rand. access memory)	1440					500	456	200
PRINTERS AND MODEMS								
Printer: Matrix (200 char per sec.)	800			656	522			600
Printer: Letter quality (96 char per sec.)	1400			918	731			824
1200 Baud Modem	150						36%	25
Other								
Minicomputer Family-Control								
Processor and Port Controller (fixed)								

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and received for the Acqco Data Base Corporation Study.

Table B-1 (continued)

	Price in 1981	Projected Percent Decrease Per Year to 1985 and 1985 Price							Expected price in 1985
		1%	5%	10%	15%	20%	25%	other	
LONG TERM MEMORY									
Cabinet for Winchester and tape	\$200							0%	\$200
80 mbyte Winchester disk/controller	1600		1473	967					1200
Tape backup cartridge with controller	1600		1473	967					1200
10 mbyte Winchester with tape backup and controllers	2300				1200				1200
16 card reader/writer (high capacity)	145				75				75
Dual Sided Double density floppy (2 mbytes) disk with controller	700			459	365				400
CUPPER DISPLAYS									
Low to med resolution monochrome terminal with text and graphics built in	2500					1000			1000
13" Med Res (512x512) color graphics terminal w/RTSC video mixing capability	5000			3280	2610				3000
RTSC Video-disc player	1600			1048		156			800
Video-disc interface	195			125		78			100
RTSC Monitor (color)	350	336	285						310
RTSC Text/graphics generator and mixer	385			251		157			200
Projection TV system	3750			2462	1960				2200
Digitalized telephone quality random access voice input	1500					650			650
RTSC Monochrome TV monitor	200							0%	200
Alphanumeric CRT (monochrome)	400	384	368						370
PRODUCTION DEVICES									
Studio quality color text/graphics character generator (quantity 1)	70,000	67,240	57,015						60,000
3 1/4" videotape editor (quantity 1)	4,300	3,500							3,500

Table 3-1 (continued)

[illegible]

These percentages were applied to the current cost estimates in step 4 to project expected or pessimistic and optimistic future costs for 1985. If a component had exhibited relatively stable price decreases historically, then only one "expected" value was projected. In these cases this value was used as the expected future cost. In other cases, averages or the optimistic or pessimistic figure was selected depending upon the judgement of industry experts. Table 8-1 presents this information.

These component costs were simply added together as they were configured into a system type. This figure was then adjusted up 20 percent to account for integration, checkout, delivery, etc.

Presentation of Component Costs

The current and projected component costs are presented in Table 8-1. The first column lists the estimated current costs for quantity 5000. The last column lists the equivalent future costs. The column entitled "Other" contains percent decreases per year of those components that are expected to have cost decreases other than the 1-25% range. The costs corresponding to these percent decrease per year are found in the last column. The other columns contain cost estimates associated with each percent decrease per year value.

Each row will have one or two elements in addition to the first and last column elements. If only one element is filled in, its value represents the expected future cost of that component. If two values appear, they represent pessimistic and optimistic cost projections. The pessimistic projection always appears to the left of the optimistic projection. As mentioned earlier, the projected cost may be one of the values entered on that row or an average of the values. The projected prices are 1981 dollars. They would have to be adjusted for general inflation.

Assumptions of Projected Component Costs

The following pages contain an economic and market description of a few of the major components for which commercial information is available. These descriptions form the basis of the assumptions made explicit in the component cost table.

Input Devices

Keyboards and Keypads. Keyboards and keypads are mature products. Millions of keyboards and keypads have been

manufactured and millions more will be produced over the next several years. Since keyboards and keypads contain many mechanical parts, their price is expected to decrease only moderately over the next few years.

There are many different styles and sizes of keypads. A typical keypad has 12 to 16 keys and costs as little as 17 dollars.

Keyboards are more standardized than keypads and typically resemble the standard typewriter keyboard. Keyboards can be purchase in large quantities for less than one hundred dollars.

Touch-panels. In contrast, touch panels represent a relatively new product. As new applications are discovered the quantity of touch panels produced will increase manyfold. Since touch panels are primarily electronic, their cost is expected to decrease substantially by 1985.

Speech input. These devices vary widely in quality and cost. We feel that only the best of the current speaker dependent, isolated or connected word technology is sufficiently accurate for widespread use in the Army. Price of this type of high quality system is currently about \$8000, but can be expected to fall rapidly by 1985.

Graphics tablets. There is unanimous support among experts contacted for the appropriateness of the data tablet for transferring linedrawings into digital format. One expert said this manual transfer is not cost effective, and recommends a solid state camera manufactured by Data Copy of Palo Alto. This expert claims that data tablets are so labor intensive that one client does all their digitizing in India because of cheap labor costs.

Data tablets are made by Summagraphics, HP, GTCO, and other manufacturers. They come with different sizes, resolution, and features. Most display system houses will sell the tablet as an option for about \$2,000. The interfacing may be standard or may require a board that costs another \$1,500 to \$4,000. (Some interface boards are equipped with their own microprocessors and handle four or more input devices.) GTCO will sell a tablet for \$600 OEM.

Most tablets come standard with a stylus. Some come with ink, some without. Some styli have up to 16 buttons. For about \$200, a "puck" is available with cross hairs and up to 16 keys.

Joysticks and trackballs. Some users recommend that the tablets should be used with joysticks and some say definitely not. Joysticks cost up to an additional \$1000, but have less interfacing requirements than data tablets. Joysticks are used primarily for identifying points on a matrix and for rotating, panning, and cursor control.

None of the industry experts questioned recommended a trackball. Some houses offer trackballs as options. Most experts said trackballs were not very popular. High quality trackballs cost between \$500 and \$1,500. Trackballs are used for continuous tracking applications (e.g., air traffic control or radar).

Use of light pens was discouraged by industry experts consulted. Where used currently, the use is primarily for menu selection.

Some houses offer a special function keypad, and some offer special function keys on their keyboard, which are user definable.

Mouse input devices. A mouse is rolled over a flat surface, and senses position by noting the revolution of its wheels. If it is picked up, it loses its place. Thus it tracks relative position, rather than absolute position as on a data tablet. The mouse can thus be relatively inexpensive. Since it is largely a mechanical device, its price is not expected to fall by much in the future.

Valuators. A valuator is a device like a "game paddle" or rheostat on a personal computer. As a knob is twisted the valuator sends corresponding signals to the computer. This device is quite simple, in high volume production, and largely mechanical. It is thus relatively inexpensive and stable in price.

Processing Devices

The computer industry and processors. The computer industry is fast becoming the world's largest industry. With industry revenues around \$50 billion, it has nearly doubled since 1975. The industry is characterized by innovation and technological changes. As component prices decrease, more and more applications become economically feasible.

One of the fastest growing sectors of the industry is the small computer business system. The technology is changing so fast that it is hard to define a "small" system. A small business system implies that most of the processing takes place on a thin board about the size of a notepad. Most of the systems have a 16 bit processor, metal oxide semiconductor (MOS) random access memory (RAM), floppy or Winchester disks, a serial or line printer, and at least one terminal. An economic

overview of the small business system is appropriate for this project because the present-tion features take advantage of small computer system processing and storage technology.

In 1980 approximately 60,000 small business systems were shipped at an average value of \$60,000. This volume is expected to reach 500,000 units by 1985 and 3,000,000 units at the close of the decade. The average cost per system is expected to drop to \$25,000 by 1985 and \$15,000 by 1990. This downward sloping cost trend is a necessary condition for the desirable features to be economically feasible.

A detailed analysis requires that we break the system into its component parts:

- CPU and I/O drivers
- Peripherals
- Software
- Storage

At the present time a 16 bit Motorola 68000 CPU chip is priced at \$200. If this is assembled onto a CPU board with a 6809 processor, memory management, serial I/O ports, parallel ports, floppy disk interface, and a RAM card, the cost rises to about \$1,500. This chip uses 32 bit words, 16 bit data paths and 24 bit addresses.

In February 1981, Intel Corp. detailed some specifications of the initial components of its 32 bit microprocessor family. The three chip set which is called a micro-mainframe uses 32 bit words, data paths, and registers and is expected to be priced at less than \$1,500. Intel's 432100 single board computer which incorporates a two chip set sells for about \$2,500. The package does not include the interface processor chip.

The present \$1,000-\$1,500 cost differential between the 16 and 32 bit processors is expected to diminish over the next five years.

In terms of the processing component of Electronic Delivery Systems, there are three basic components: (1) the microprocessor chip; (2) the surrounding components which provide a working environment (i.e., interfacing, ports, fan, power supply, etc.), and the assembly labor.

Over the next several years, millions of chips will be produced. As a result, the computing power will multiply as the cost falls to a fraction of present figures.

The surrounding components are expected to decrease in costs over the next several years but not as dramatically as the chip component. This is because these components are more mechanical in nature than the chip components.

In contrast, the labor component should remain about constant in real terms over the next several years. Some labor cost savings may result from the trend toward more sophisticated components that would handle multiple tasks and decrease the assembly time.

Random access memory (RAM). Internal memory represents a fairly substantial cost component of the configuration. RAM is still experiencing some innovation as more densely packed chips are replacing older chips. The 16K bit chips (which displaced the 4K bit chips) have decreased from \$9.00 to \$2.50 per K bit in the last two years. The new 64K bit chips are expected to be cost competitive on a per byte basis by early 1983. Table 8-2 illustrates the tremendous growth of 16K RAM devices.

Table 8-2

NUMBER OF 16-K RAM DEVICES SHIPPED

1975	Less than 1,000
1976	Less than 100,000
1977	1.8 million
1978	20 million
1979	60 million

Printers and Modems

Some devices are usually available from a central facility but are not required by every terminal. Printers and modems fit this category. While there are many types of printers, the applications envisioned here would make use of only two basic types: a dot matrix, in-house quality printer of about 200 characters per second capacity, and a letter quality printer for word processing which would run at about 55 characters per second. A number of innovations are taking place in this field and quantities are increasing. Therefore price reductions of 10 to 15 percent per year can be expected in printers.

It is anticipated that until data networks become more widespread (after 1985) the primary means of realtime data transfer between Army training centers will be via voice grade telephone with modems. The upper limit for reliable communication by voice grade phone is about 1200 Baud (roughly 120 characters per second). Modems are almost entirely electronic, and their prices are falling rapidly. We expect integrated chip circuits to be widely available for modems by 1985, and therefore project quite low prices.

Long Term Memory

Winchester Disks. High density hard magnetic disks based on Winchester technology are becoming very popular. Today a high volume purchase of 30 mbyte Winchester disks with controllers might cost \$1600 per unit. Another \$1600 would

need to be added for the tape backup with controller, and another \$200 would be required for the cabinet. Moderate price decreases of 5-10 percent can be expected for the disk and tape as volume increases. No decreases are expected in the cabinet.

A 10 mbyte Winchester with tape and controllers should be available in a small package for approximately \$2300 in large quantities. This price can be expected to fall by about 15 percent per year.

Data cards. Data cards (ID cards), which are similar to current credit cards with magnetic stripes, are gaining in information density. Optical formats are being prototyped as well as magnetic formats. Simple reader-writers for these high capacity cards are still in the prototype stage, but it has been estimated that in high volume their current price would be approximately \$145, and that a 15% annual decrease can be expected through 1985.

Floppy disks. Floppy disks are growing in density of packing, and prices for the same storage capacity are falling. Moreover, very large scale integrated chips can be used for the controllers. Price decreases of 10 to 15 percent per year are projected for dual sided double density floppies of approximately 2 megabyte capacity.

Output Devices

NTSC color TV monitors. Approximately 10 million color TV sets were sold in the U.S. in 1980. The sales of color TV sets is expected to increase to approximately 13 million per year in 1985. The increase is due to both technological and socio-economic factors. Cable TV, video-cassette recorders, videodisc player, video games, home computers, etc., are all making the color TV a more popular product. By the same token, inflation and rising fuel costs are influencing consumers to spend their entertainment dollar on activities centered around the home TV.

Industry experts do not anticipate major decreases in prices, but at best only slight decreases (1-5 percent per year) since more and more features will be incorporated into a single TV set. An industrial type NTSC color TV monitor sells for \$350 in larger quantities.

Projection TV's. This is a new product that is gaining popularity because of the increasing entertainment time that is spent in the home. Fewer than 100,000 projection systems were sold in 1980. The annual figure is expected to surpass 400,000 units in 1985. The present cost of a durable industrial/educational system is approximately \$3750 in large quantities. Decreases in price as well as increases in quality are anticipated for projection TV systems.

NTSC monochrome monitors. Since 90 percent of American households have at least one color TV and 40 percent have two or more, this leaves little growth opportunity for black and white TV's. Zenith predicts the penetration rates of color to rise from 72 percent in 1975 to 95 percent of total U.S. households. This trend will prevent the cost of monochrome monitors from decreasing much over the next five years. An industrial monochrome TV can be purchased for \$200 in large quantities. This does not include built-in text or graphic capability.

Alphanumeric terminals. Alphanumeric CRT's are a mature product and the rate of growth and innovation is slowing. Shipments of U.S. manufacturers are expected to reach 775,000 units in 1985 from 510,000 units in 1980. At the end of 1980 the total installed base was estimated to be 2.2 million units. Most alphanumeric terminals retail from \$200-\$4,500. The price of a CRT is expected to decrease only slightly in real terms over the next four years. For the applications presented here, a combined text and graphics capability is generally preferred over alphanumeric only. If an alphanumeric CRT is used, it would most likely be toward the low end of the cost/feature spectrum.

Monochrome graphic terminals. In 1980, approximately 60,000 graphic display terminals were shipped by U.S. manufacturers worldwide. This figure is expected to approach a quarter of a million by 1985. For over ten years direct view storage tube (DVST), a vector graphic technology, has dominated the monochrome terminal market. DVST is a mature technology and significant advances that will increase performance or decrease cost are not anticipated. The Tektronix 4014 DVST monitor sells for approximately \$8,000 in large quantities. It has a resolution of 1024 x 1024 lines and is monochromatic (1024 x 780 within the viewed area).

The storage requirements for this degree of resolution for a raster scan system have been too costly for this technology to compete in the market, since one bit is required for each pixel of resolution. Thus over 1 million bits of memory are required to support a 1024 x 1024 display. However, recent semiconductor advances are rendering the bit-mapped raster scan system an economically feasible alternative. The Genisco G-1000 is a 1024 x 1024 monochrome (1024 x 792 within the viewed area) display monitor that sells for \$10,000 in quantity one. In large quantities, the price would likely be a little more than half this amount.

One could expect to pay about \$2500 for large quantities of medium resolution monochrome terminals (512 x 512 or 360 x 720). A low resolution monochrome terminal can be purchased for several hundred dollars.

Color graphic terminals. Innovations in storage and color printing technology have sparked the growth of color graphic displays. Experts predict that the 15,000 color displays shipped in 1979 will expand to 200,000 per year by 1983. This growth is due in large part to the increased cost effectiveness of raster scan display monitors which are easily adaptable to color.

A 1024 x 1024 graphic display monitor with the capability to display 16 colors is priced at \$18,000 (Chromatics CGC7900 Model II). The price drops to \$3,000 - \$6,000 for medium resolution 8 color monitors (480 x 384 - 640 x 480). A low resolution color monitor (160 x 192) ranges in cost from several hundred to several thousand dollars.

Flat panels. Flat panels which display more than 200 characters at one time represent a very new product. At the present time, none of the flat panel technologies are cost competitive with CRT's for the typical desk-top applications. However, the space and visual advantages of flat panel displays are inducing manufacturers to develop cost competitive flat panel alternatives to the CRT. The current cost of a 512 x 512 flat panel display is approximately \$4,500. The militarized version that is in compliance with military specifications can be purchased for \$10,000. The Interstate Electronics PD3000 plasma display flat panel conforms to the following military specifications: MIL-STD-461, MIL-STD-810C, and MIL-E-5400R.

NTSC videodisc players. There are many competing formats of videodisc players. For the applications presented here, the player must be able to refresh a single frame (e.g., of text and graphics) indefinitely and must include a microprocessor. Because of the heavy use expected, a commercial/industrial player is required. Currently, such players using laser optics are priced at about \$1600 in large quantities. As cumulative experience increases, the price can be expected to fall 10 to 20 percent per year on the average.

Videodisc interface. In order for the videodisc to be controlled by a computer, a hardware interface is needed. Some videodisc players include this as a standard item, while for others it is an option. As an option the cost today is under \$200. Since this is electronic, the cost will likely fall to about \$100.

NTSC text/graphics generator and mixer. In order to place text and graphics on the TV screen, a generator is necessary. This system may include a video mixer which combines images from the videodisc with computer generated text and graphics. This permits overlays for generative items, to echo the student's response, and to correct errors. The Texas Instruments TI9918 chip is an inexpensive means to perform those functions today. In a working environment with the

associated circuitry, the system would be priced at approximately \$385 in large quantities. This price can be expected to fall about 10 to 20 percent per year if demand increases.

Voice output. Many kinds of voice output are available, ranging from relatively low quality for under \$50 to extremely high fidelity digital recording systems for tens of thousands of dollars. The system which most closely fits the needs of Army technical training, where revision rates are very high, is likely to be a fairly straightforward analog to digital conversion (e.g., pulse code modulation or adaptive delta modulation). Other systems using, for example, linear predictive coding yield lower costs, generally lower fidelity, and greater difficulty in making the initial encoding of voice. A telephone quality random access pulse code modulation (PCM) voice output system would cost approximately \$1500 in large quantities today. Integrated circuits could be used to bring this cost down to approximately \$650 by 1985 if the cumulative experience and sales burgeon as expected.

Production Devices

Studio quality text/graphics generator. In order to prepare high quality text and graphics directly for video, a studio quality system is needed which offers multiple fonts, color, shading, and spacing. Only one such system is needed for each major authoring shop. The best of these systems in quantity one cost from \$60,000 to \$70,000 today. Small to moderate price decreases are expected, given the very small volume for these systems.

Three-quarter inch videotape editing equipment. Each authoring group needs a videotape player, and preferably a limited editing system in order to review tapes during the authoring and production steps. Only one videotape editing system is needed for each authoring group. A simple system currently is priced at about \$4300, with slight decreases possible over the next four years.

Militarized Components

The term "militarized" is ill-defined. Separate specifications exist for vibration, temperature, salt spray, and many other factors. What is intended here is ruggedness for use in forward areas, but in somewhat protected maintenance situations. Depending on the specifications to be met, militarized equipment may cost two to 20 times as much as commercial hardware. For our applications, electronic component costs were for the most part doubled, though keypads and keyboards were increased more based on cost history.

Militarized components often employ state of the art, low volume components. An example is flat panel displays. These can be expected to drop rapidly in price if the basic technology is picked up in the industrial and consumer arenas.

Magnetic bubble memory is currently available. As noted in the table, its cost is expected to drop about 25 percent per year through 1985.

Hand Held Components

The hand held system for data entry (e.g., scoring and inventory) requires battery powered, small circuitry. Its processing and display requirements are limited. Except for the power supply and keypad, component prices are likely to come down rapidly as volume increases.

Costing Assumptions

Now that component costs have been identified, they can be combined with the benefits of the presentation features, and alternative configurations can be analyzed in light of the Army's training requirements.

The five system types, which are adaptable to all of the scenarios analyzed in this and previous studies, are analyzed individually. First, a recommended configuration is defined for the particular system type. Then the recommended configuration is defended based on the cost/benefit trade-offs. In addition a lower cost alternative is configured. Finally, the add-on options to the recommended configuration are delineated and the cost/benefit trade-offs of these options are discussed.

It is intended that this approach take ACTO another step further toward the definition of that modular set of components suitable for all scenarios presented in chapter 2 (and discussed in detail in the ACTO report on storage media (Bunderson, Pett and Bearnsen, 1981). In other ACTO studies further analysis can be accomplished bearing on high risk/high cost trade-offs, and detailed specifications can be written.

A few summary observations from our research may help to guide the following discussion:

Some selection criteria are more important than others. The current Cue/See delivery system provides color, sound, motion, and student control of pacing. In other words, one low-cost system already in use delivers many of the features investigated here. The TBC instruction is a quantum leap over older approaches.

Why then, if the delivery system and the materials are good, are they not much used? There are many reasons, and most of them will confront any new delivery system. Historically, when one investigates changes that stick one usually finds that they:

1. are new tools that leverage work by making it more efficient, thereby providing a competitive advantage over older tools.
2. are organizational or structural changes that add a layer of people.
3. are easily monitored so that observers can easily see if they are used.
4. create a constituency that wants to support the innovation.

From our observations, any individualized instruction like TEC can conflict with the need for NCO's to maintain responsibility for training. It can thus alienate rather than create a constituency. We observe NCO's using TEC lessons the night before they will present the stand up lecture. Or TEC lessons used by groups of soldiers because training is for teams. The delivery system must either have the power to change the structure (as the automobile changed urban society) or it must adapt to an existing constituency.

In order to be successful, the new electronic delivery system must provide in great measure the most important feature--interaction. In our judgment this feature far outweighs all the others. If NCO's and soldiers have a sufficiently powerful tool that provides interactions, they will find ingenious ways to get the most from it regardless of the specific input and output configuration. Interaction requires a computer. With that capability, it is possible to replicate dynamic interchanges between an excellent instructor and a soldier. There is a threshold, a minimum level of power, beyond which order of magnitude increases in productive work become possible. That power in computers is now becoming widely available. It is a new tool which can leverage the work of soldiers, instructors, and commanders. Such a tool is the most important characteristic of changes that stick. It is the central element of the electronic delivery system.

Nothing else matters about the electronic delivery system if it is not used. Computer interactions that are engaging, have real importance for the job, and are sensorily stimulating have the greatest potential of being used.

Other features can be roughly ranked from most to least importance as sound, color, resolution, photo realism, and motion. As described in detail in Chapter 3, there is seldom one best level of these features. Instead, the degree of resolution, and the best use of sound, color, photo realism, and motion depends on the content and the soldier.

The following sections present alternate configurations for each system type.

Basic System Components

The basic system applies to all desk top applications in a sheltered environment. The militarized version for use in the field is treated as an option within the basic system. Hand held components are presented separately.

The basic system includes the following components discussed below: processing, higher order languages, storage, software user utilities, and shared resources at a site.

Figure 8-1 presents the candidate features for the basic system. For each type of component, a low cost configuration is also presented where feasible. Projected original equipment manufacturer's (OEM) prices for 1985 are included. These prices are based upon a quantity 5,000 purchase. The prices are expressed in real 1981 dollars, and therefore must be revised upward to reflect general inflation in order to arrive at nominal 1985 dollars.

Processing. The preferred central processor for this system is the 32 bit military computer family system with 256 K of random access memory (RAM) minimum. The 32 bit military family was selected because it is likely to be the standard throughout the Department of Defense.

An optional system for field use requires a militarized 32 bit processor and militarized random access memory. As might be expected, this option is more expensive.

The minimum cost option would be to use a 16 bit commercial microprocessor with 256K of RAM. The cost differences between the 32 bit and 16 bit micro processors are expected to be minimal in 1985 and to decrease thereafter. The 16 bit micro offers sufficient capability to accomplish sophisticated training. It is therefore one of the candidate systems. On the other hand, a standard microprocessor which is compatible with others throughout the Department of Defense may have long run cost benefits which transcend the immediate hardware acquisition cost.

Hardware Links. We recommend that each system include a variety of serial and parallel ports using the standard connectors. This will greatly enhance the ease of plug-compatible, modular hardware integration, which was one of the criteria presented earlier for electronic delivery systems. Optional connectors may make use of ports which are expected to be standardized but have not yet come into general use, and militarized ports with ruggedized connectors for field use.

RECOMMENDED BASIC SYSTEM COMPONENTS

(NOT FOR HAND HELD UNITS)

PROCESSINGPROJECTED GEM
PRICE IN 1975PREFERRED

32 BIT MILITARY COMPUTER FAMILY CENTRAL PROCESSING UNIT (CPU) IN WORKING SYSTEM (I.E., INCLUDES POWER SUPPLY, BUS, PORTS, ETC.)	\$ 520
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256K RANDOM ACCESS MEMORY (RAM) MINIMUM	\$ 300
-----------------------------------------	--------

OPTIONAL

MILITARIZED 32 BIT CPU FOR USE IN FIELD	\$1040
MILITARIZED 256K RAM FOR USE IN FIELD	\$ 600

MINIMUM COST

16 BIT COMMERCIAL MICROPROCESSOR	\$ 210
AND 256K RAM (MINIMUM)	\$ 300

LANGUAGES

ADA

FORTRAN

PASCAL

BASIC

C

SYSTEM SHOULD SUPPORT STANDARD
VERSIONS OF THESE LANGUAGES SO
EXISTING SOFTWARE CAN BE USED.
LANGUAGES NEED NOT BE AVAILABLE
SIMULTANEOUSLY.

Figure 8-1
Recommended Basic System Components

STORAGEPREFERRED

CONNECTION TO ON-SITE SHARED STORAGE CONSISTING
OF WINCHESTER DISK AND CONTROLLER (30 MEGABYTES) \$ 650
WITH TAPE BACKUP (CARTRIDGE) AND CONTROLLER,
SHARED BY FOUR USERS.

OPTION

ID CARD READER/WRITER \$ 75
OR MILITARIZED SOLID STATE 1 MEGABYTE MEMORY FOR USE \$1425
IN FIELD.
OR DEDICATED 10 MEGABYTE WINCHESTER DISK WITH TAPE \$1200
CASSETTE BACKUP AND CONTROLLERS FOR STAND-ALONE
SYSTEM.

MINIMUM COST

DUAL SIDED DOUBLE DENSITY FLOPPY DISK (2 MEGABYTES) \$ 400
WITH CONTROLLER.

SOFTWARE USED UTILITIESPREFERRED

DATA BASE MANAGEMENT SYSTEM
AND REPORT GENERATOR
AND ELECTRONIC MAIL
AND WORD PROCESSING
AND SORT/MERGE
FREE WITH VERY
LARGE HARDWARE
QUANTITIES.

Software Communication Protocol. It is proposed that both synchronous and asynchronous communication protocols be available for the system. This is another major factor in the ease with which systems can be linked in a network for exchange of information. Some of the protocols are relatively cumbersome because they must handle a very wide variety of conditions. Protocols for transfer of information at a local level need not be as complex as some of the standard protocols presented here.

Higher Order Languages. We recommend that the system run a variety of higher languages, and not be dedicated to a single language type. This will permit use of existing materials to a much greater extent. The languages recommended are ADA, FORTRAN, Pascal, BASIC, and "C". These languages should all be available to run on the system, but need not be available simultaneously.

Storage. The preferred storage system consists of a storage station which utilizes a 30 megabyte Winchester disk with tape cartridge backup and controller. This common storage is shared by from two to 100 users. Our observations at a number of military bases indicate that the average number of work stations connected to each storage station is likely to be in the range of four. Therefore in estimating costs, the \$1200 cost of the Winchester disk and its controller, the \$1200 cost of the tape backup system and its controller, and the \$200 cabinet is divided by an average of four users to arrive at an approximate cost of \$650 per user for this type of storage. Optional means of storage include an ID Card reader/writer, militarized solid state memory for use in the field, and dedicated 10 megabyte Winchester disk drives with tape backups and controllers for use on a stand alone system.

The minimum cost option uses a dual sided, double density floppy disk containing between two and four megabytes, with its controller.

Software User Utilities. It is recommended that a number of utility software packages be available on almost every system. If the Army makes a large purchase of hardware, some or all of these software utilities should be provided free from the manufacturer. These utilities include a data base management system which would be especially useful for NCO's, commanders, and others charged with administration. Other utilities include a report generator which selects and reports data from a data base, electronic mail, word processing, and a sort/merge capability which can be used to manipulate data files.

Shared Resources At A Site. It is not necessary to equip every electronic delivery system with every option. In fact, that would be very wasteful. Instead, we recommend that some capabilities be available on a site basis which can then be used to support many work stations. Among the utilities recommended are a 200 character per second dot matrix printer for producing low quality hard copy printouts and a 1200 Baud modem for communication with other units. As an option, a letter quality printer can be available for word processing applications. This printer will operate at a slower speed than the dot matrix printer described above, but will produce higher quality output.

Analysis for the Instruction System.

This system type uses the basic system components described above, and adds a response and a display capability. Figure 8-2 presents the candidate features for this system, and Figure 8-3 presents the cost summary.

Response. The preferred components for this system include both a keypad and a touch panel. The keypad is used primarily for functional commands, while the touch panel permits interactions with variable information as it is presented on the screen. These two components may be used singly or in conjunction.

Optional response mechanisms include a high quality voice input system, a keyboard where users are typists and where the volume of information is high, an inexpensive joy stick or mouse as an alternative to the touch panel, a valuator (e.g., rheostat or game paddle on the Apple), and a track ball.

These options reflect a sense from experiment five of the present study and from our research that a keypad and touch panel system are most appropriate for the wide variety of soldiers' applications. The keypad and touch panel can be used in conjunction or by themselves. The optional capabilities were judged to have fewer applications, but to be adequate in terms of the selection criteria.

Display. The preferred display feature includes medium resolution color graphics and color motion presentation capability (e.g., NTSC videodisc player and controller interface). Options include a projection television system for large audiences, and a digitized, random access telephone quality voice output system.

An alternative system might be considered as an option. This system is all digital, and sacrifices color and the realism available on a videodisc while maintaining a graphics capability (albeit of lower quality). This display system uses a low to medium resolution (e.g., 300 X 400 pixels) monochrome terminal with text and graphics packages.

A minimum cost option maintains the color and motion capabilities which might be provided by a videodisc, but significantly decreases the text and graphics capability. This system consists of

RECOMMENDED FEATURES FOR EACH SYSTEM TYPE

A. INSTRUCTION IN A SHELTERED ENVIRONMENTRESPONSEPROJECTED OEM
PRICE IN 1982PREFERRED

KEYPAD	\$ 15
AND TOUCH PANEL	\$ 50

OPTIONS

HIGH QUALITY VOICE INPUT	\$ 850
OR KEYBOARD	\$ 70
OR LOW RESOLUTION JOYSTICK	\$ 25
OR LOW RESOLUTION MOUSE	\$ 50
OR VALUATOR (E.G., RHEOSTAT)	\$ 20
OR TRACKBALL	\$ 150

DISPLAYPREFERRED

13" MED. RESOLUTION (E.G., 512x512 PIXEL) COLOR	\$3000
GRAPHICS TERMINAL WITH NTSC VIDEO CAPABILITY	
AND NTSC INDUSTRIAL VIDEODISC PLAYER	\$ 800
AND VIDEODISC INTERFACE FOR CONTROL ONLY	\$ 100
OR LOW TO MEDIUM RESOLUTION (E.G., 300x400 PIXELS)	\$1000
MONOCHROME TERMINAL WITH TEXT/GRAPHICS	

OPTIONS

PROJECTION SYSTEM FOR LARGE AUDIENCES FOR NTSC	\$2200
COLOR	
OR DIGITIZED RANDOM ACCESS VOICE OUTPUT	\$ 650

MINIMUM COST

NTSC USA BROADCAST STANDARD COLOR MONITOR	\$ 310
AND NTSC TEXT/GRAPHICS CHARACTER GENERATOR	\$ 200

Figure 8-2
Recommended Features for the Instruction System

COST SUMMARY

A. INSTRUCTION IN A SHELTERED ENVIRONMENT

PREFERRED

32 BIT CPU	\$ 520
256K RAM	250
1/4 SHARE OF	
30 MBYTE DISK/TAPE	650
KEYPAD	15
TOUCH PANEL	50
512x512 COLOR	3000
GRAPHICS/TERMIN.	
WITH NTSC VIDEO	
NTSC VDISC PLAYER	800
VDISC CONTROLLER	100
	<u>5425</u>

INTEGRATION ETC	1085
(20%)	<u>6510</u>

MINIMUM COST VIDEO

16 BIT CPU	\$ 230
256K RAM	250
1 MBYTE FLOPPY	75
KEYPAD	15
TOUCH PANEL	50
NTSC MONITOR	310
NTSC VIDEODISC	
PLAYER	800
NTSC CHAR. GEN	200
VDISC CONTROLLER	100
	<u>2375</u>

INTEGRATION (20%)	475
	<u>\$2850</u>

ALL DIGITAL OPTION

32 BIT CPU	\$ 500
256K RAM	250
1/4 OF 30 MBYTE	650
DISK/TAPE	
KEYPAD	15
TOUCH PANEL	50
300x400 MONOCHROME	
GRAPHICS TERMIN.	1000
	<u>2525</u>

INTEGRATION (20%)	505
	<u>\$3030</u>

Figure 8-40
Cost Summary for the Instruction System

an NTSC color monitor, an NTSC text and graphics character generator, videodisc, and interface control. This type of system might be limited to placing 24 lines of 31 characters each on the screen, or low resolution graphics on the order of 192 X 256 pixels.

The reason for specifying color in the preferred system is that an electronic delivery system is self paced, and color has been shown to increase performance in self paced instruction, as well as to result in higher retention. These effects, as noted above, are available only if the learner is given time to assimilate the color. This system would allow for color coding, which has been shown to result in faster and better comprehension. Color has also been shown to be preferred over black and white, and it may thus be a factor in decreasing attrition.

If a videodisc is planned in order to present motion sequences, the system should also be able to provide color in order to take full advantage of the capabilities of the videodisc. The system proposed here uses a single terminal to present both medium resolution computer-controlled graphics and NTSC video images. This system uses a comb filter, with three color planes, allowing up to eight color combinations for graphics, which can be overlayed on the video image. Either image may also be presented separately.

The inclusion of a color graphics terminal significantly increases the cost of the preferred system over the cost of either an all digital system or a low resolution NTSC-only system. What does the medium resolution system buy in relation to a low resolution system? And what does the color motion capability buy in relationship to a low to medium resolution monochrome all digital graphics system?

WICAT has had considerable experience using low resolution color text and graphics overlays on videodisc images. We find this capability to be extremely important for generative items and for making corrections to the videodisc presentation. On the other hand, the text limitations are such that only minimal amounts of poster-like information can be placed on the screen. It would not be feasible to use the system to present much text. Moreover, the graphics capability is limited by the 192 X 256 pixel resolution and by the pragmatic requirement to define lines of several pixels width. The system is usable, and yields attractive graphics for large figures. On the other hand, the Texas instruments 9918 video display processor which we use is not well adapted to presenting fine details, for example meter faces. Therefore, a medium resolution (approximately 512 X 512) system adds the capability to present relatively fine lines. This makes the difference between being able to present

meter displays, for example, in a two dimensional simulation or not. This resolution is approximately equivalent to that of the PLATO system. We have prepared an extensive simulation on PLATO, and find it a very useful tool to have this level of resolution available.

The second comparison is between the color motion features available in the preferred system and the monochrome low to medium resolution all digital graphics system. We feel confident from the literature review and other research conducted for this study that a great deal of very effective training can be presented with a low to medium resolution monochrome graphics system as described here. The advantage of using the computer graphics for either of the systems is that computer generated graphics permit rapid modifications to a program to be made on-site, as opposed to the delays associated with making changes on a videodisc. Security can also be easily achieved using the magnetic medium. To make optical videodiscs systems secure is more difficult. The videodisc material can simply be locked in a safe, much as classified printed material is today. Nevertheless, while it is in the player it is vulnerable. This is somewhat less the case with a magnetic medium. Both the videodisc and computer generated text and graphics permit zooming in. On the videodisc this is accomplished by a succession of pictures taken ever closer to the subject. In a graphics system, zoom may be accomplished through hardware and software manipulation of a single data base.

The advantage of color motion over monochrome stills and animation is that some procedures, where motion is critical or where time sequences must be portrayed, can best be presented in a video format. Moreover, human models can be much more easily presented by a video system than by computer graphics. The video also permits presentation of existing slide/tape, video tape, and film materials. In these areas, videodisc color and motion sequences have the advantage. On the other hand, the cost of preparing a videodisc and the difficulty of making changes are disadvantages. On balance, we feel that marrying the color and motion features of a video system with the capabilities of a medium resolution graphics system yields all of the benefits of both approaches while minimizing their respective disadvantages.

The other element of comparison for the preferred system in relation to the all digital monochrome graphics system is in the area of sound. In some sense the sound comes free with motion on a videodisc. That is, buying the motion feature also buys the sound capability. This statement can be misleading however, unless still frame audio is available. Still frame audio permits up to 30 seconds of audio to be presented with each still picture. Currently, 30 frames of pictures must be used for each second of audio. If the videodisc is used for audio without a still frame capability, the video segments are almost wasted because a single still video image is repeated 30 times per second while the audio plays. The same comments about videodisc sound apply as were made about videodisc video. That is, the disk is difficult to change, expensive to prepare materials for, and requires a long period of time until the disk can be remastered and copies returned to the field. Moreover,

while the videodisc permits rapid searching and therefore a form of random access audio, it is somewhat limited in this regard by the speed with which various motion and audio segments can be accessed. Therefore, while the preferred system does indeed offer a capability for sound, it is not the computer-generated or very fast random access voice and sound which is available on some other systems. There is nothing preventing the addition of such a capability to the preferred system. However, these capabilities are not required. Videodisc audio is likely to be acceptable for most applications.

The all digital graphics system could also have the random access audio provision added to it. In this way it could have even more powerful sound capabilities than the basic preferred system. Sound is not a sufficiently high priority feature by itself (i.e., apart from color video motion) to be included in a low cost system. Figure 8-3 presents a cost summary of the three basic configurations described above.

Analysis for the Administration/Management System

A preferred and a minimum cost configuration have been prepared for this system type. The two configurations with their options are compared in Figure 8-4. Figure 8-5 presents a comparison of the expected total costs for the two systems in their basic configurations.

The primary difference between the preferred and the minimum cost systems are the CPU, the means of storage, and the presentation device. The preferred system makes use of the 32 bit military computer family CPU while the minimum cost version uses a 16 bit commercial CPU. These differences were described in the previous section. The preferred system also uses a shared 30 megabyte Winchester disk with tape backup. The minimum cost configuration uses a floppy disk. Both use a keyboard because it is expected that administration personnel will know how to type and because the volume of data entry makes a touch panel or keypad less attractive. Finally, the preferred system uses the medium resolution color terminal which was described with the instruction system type, while the minimum cost configuration uses the monochrome graphics terminal described in that same system type. It should be noted that neither system includes a videodisc. It should also be noted that these systems are intended to be plug compatible and modularly interchangeable. By this is meant that to make the administration/management system into an instruction system the appropriate peripherals for the new

B. ADMINISTRATION MANAGEMENT IN A SH-LEVEL ENVIRONMENT RESPONSE

PREFERRED

KEYBOARD \$ 70

OPTIONS

TOUCH PANEL	\$ 50
OR COMMERCIAL QUALITY VOICE INPUT	\$ 300
OR KEYPAD	\$ 15
OR LOW RESOLUTION JOYSTICK	\$ 25

PROJECTED CEN
PRICE IN 1982

DISPLAY

PREFERRED

MEDIUM RESOLUTION (512x512) COLOR CRT \$3000
W/MED. RESOLUTION TEXT/GRAPHICS GENERATOR

MINIMUM COST

LOW TO MEDIUM RESOLUTION (E.G., 400x300) \$1000
MONOCHROME CRT

Figure 8-4
Recommended Features for the Administration System

COST SUMMARY

B. ADMINISTRATION/ MANAGEMENT IN A SHELTERED ENVIRONMENT

PREFERRED

32 BIT CPU	\$ 520
256K RAM	290
1/4 SHARE OF 30	600
1 MBYTE DISK/TAPE	
KEYBOARD	70
512x512 COLOR	<u>3000</u>
TERMINAL	
	4480
INTEGRATION	<u>890</u>
(20%)	
	\$5376

MINIMUM COST

16 BIT CPU	\$ 210
256K RAM	290
2 MBYTE FLOPPY	400
KEYBOARD	70
320x240 MONOCHROME	
TERMINAL	<u>1000</u>
	1970
INTEGRATION	<u>394</u>
(20%)	
	\$2364

Figure 8-5
Cost Summary for the Administration System

required features would simply be plugged in. This modularity and interchangeability is a critical factor in meeting the decision criterion which specifies low hardware ownership costs and high benefits for plug compatible components. Availability of systems is likely to be maximized if parts are interchangeable. It could be expected that both systems would include access to an on-site modem for connection to external computer networks and data basis.

The preferred system uses a shared memory so that information can be readily accumulated in a central data base and shared among a number of users who are in close physical proximity (i.e., wherever a coaxial cable can be run). The minimum cost system uses a floppy disk which would be physically transported to another system if someone else were to need the data.

The case for the expensive medium resolution color terminal as opposed to a lower resolution monochrome terminal is less strong for this system type. Most of the evidence supporting the use of color for management presentations is anecdotal. The cost difference is over \$3,000. Therefore, while we recommend a color higher resolution system for this system type, we feel that the cost/benefits case is less strong. In fact, it is likely that the choice of terminals for the administration/management system would be determined by the choice of terminals for the instruction system. If the higher resolution color terminals are chosen for the instructional system, then compatibility for the administration/management system would be valuable. On the other hand, if cost were extremely critical, the lower resolution monochrome system or the NTSC video only system might be chosen. If the instruction system is configured with the lower resolution monochrome terminal, then the administration/management system would certainly use the same terminal. If the instruction system uses the NTSC video only terminal, then a separate text and graphics terminal would be required for administration.

Analysis for the Job Aiding System

Figure 8-6 presents the preferred and minimum cost components for this system type. Figure 8-7 presents the cost summary for comparing the two configurations.

The CPU's for both systems are militarized. One uses a 32 bit CPU while the other one uses a 16 bit CPU. Both use militarized RAM. Both also use a militarized one megabyte solid state memory.

Although there is no difference between the preferred and minimum cost systems for the solid state memory, the quantity of this memory is a critical determinate of total system cost.

C. JOB AIDING IN THE FIELDRESPONSEPREFERRED

MILITARIZED KEYPAD	\$ 90
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OPTIONAL

MILITARIZED KEYBOARD	\$ 600
OR MILITARIZED TOUCH PANEL	\$ 100
OR MILITARIZED HIGH QUALITY VOICE INPUT	\$1700

DISPLAYPREFERRED

MILITARIZED FLAT PANEL	\$3000
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OPTIONAL

MILITARIZED VOICE/SOUND OUTPUT	\$1300
--------------------------------	--------

Figure 8-6
Recommended Features
for the Job Aiding in the Field System

COST SUMMARY

C. JOB AIDING IN THE FIELD

PREFERRED		MINIMUM COST	
MILITARIZED 32 BIT CPU	\$1040	MILITARIZED 16 BIT CPU	\$ 780
MILITARIZED 256K RAM	580	MILITARIZED 256K RAM	580
MILITARIZED 1 MBYTE SOLID STATE MEMORY	1425	MILITARIZED 1 MBYTE SOLID STATE MEMORY	1425
MILITARIZED KEYPAD	90	MILITARIZED KEYPAD	90
MILITARIZED VOICE INPUT	1700		
MILITARIZED FLAT PANEL	3000	MILITARIZED FLAT PANEL	3000
	7835		5825
INTEGRATION (20%)	1567	INTEGRATION (20%)	1165
	<u>\$9402</u>		<u>\$6990</u>

Figure 8-7
Cost Summary
for the Job Aiding in the Field System

for both systems. The ACTO Storage Media Project estimated that as much as 15 megabytes of solid state memory might be required for this job aiding application. We have estimated that magnetic bubble memory in quantity 5,000 purchases in 1985 will cost approximately \$1425 per megabyte. These prices are in terms of real 1981 dollars, and must be adjusted for inflation. Therefore if 15 megabytes is required instead of one megabyte, the cost of this system could reach nearly \$30,000. This is clearly far out of range of tolerable costs. We therefore feel that the kinds of job aiding materials placed on this system, and the scenarios for their use, should reflect the more conservative memory figures used here.

Both the preferred and the minimum cost systems use a militarized keypad. The preferred system, however, includes a voice input system as an aid to the soldier when hands and eyes are busy. There is not a good body of research yet to describe the efficiency gains to be achieved with voice input. However, anecdotal evidence over the last decade indicates that for specific applications where hands are usually full (e.g., baggage handling, quality control inspections, and numerical machine coding) voice input can make a significant difference. The inclusion of a voice input system in the preferred configuration is therefore a matter of opinion, and subject to verification in field evaluations.

Both the preferred and the minimum cost systems use a militarized flat panel display. The display is projected to be a monochromatic system.

No videodisc is recommended for job aiding in the field because of the difficulty in ruggedizing a videodisc player. However, the videodisc may be an excellent choice for garrison job aiding.

Analysis for the Authoring System

Figure 8-8 presents the system alternatives for this system type. Figure 8-9 presents costs for the preferred and minimum cost basic systems. Both configurations add a graphics tablet for entry of graphics information, and whatever keypad, touch panel, and valuator data entry capabilities are required to match the capabilities of the instructional delivery systems. A keyboard is also added for interaction with an authoring management system.

The primary difference between the preferred and the minimum cost systems is in the display terminal (medium resolution color graphics with NTSC video vs. a low to medium resolution monochromatic

COST SUMMARY

D. AUTHORING

PREFERRED

32 BIT CPU	\$ 520
256K RAM	290
KEYBOARD	70
HI RESOLUTION GRAPHICS	450
TABLET	15
KEYPAD	50
TOUCH PANEL	20
VALUATOR	3000
MEDIUM RESOLUTION (512x512 PIXELS)	
COLOR GRAPHICS TERM- INAL W/NTSC VIDEO	800
NTSC INDUSTRIAL VIDEOCDISC PLAYER	
VIDEOCDISC CONTROL INTER- FACE	100
	<hr/>
	\$5315
INTEGRATION (20%)	1063
	<hr/>
	\$6378

ALL DIGITAL

32 BIT CPU	\$ 520
256K RAM	290
KEYBOARD	70
HI RESOLUTION GRAPHICS	450
TABLET	15
KEYPAD	50
TOUCH PANEL	20
VALUATOR	3000
LOW TO MEDIUM RESOLUTION (E.G., 300x400 PIXELS) MONOCHROME MONITOR W/TEXT/GRAPHICS	1000
	<hr/>
	\$2415
INTEGRATION (20%)	483
	<hr/>
	\$2898

STUDIO QUALITY COLOR TEXT/GRAPHICS CHARACTER GENERATOR	\$60,000
3/4" VIDEOTAPE EDITOR	3,500

Figure 8-9
Cost Summary for the Authoring System

monitor with text and graphics). The choice between these two presentation feature components will surely be determined by the selection made for the authoring system.

If the instructional delivery system chosen includes a color and motion video capability, then the authoring and production system type must include a videodisc player, studio quality color text and graphics character generator, and video tape editor. Naturally, these resources are shared across a large number of users. Nevertheless, they do represent substantial costs. For example, the studio quality character generator can be expected to be priced in the \$60,000 range.

Analysis for the Rating and Inventory System

This system is presented in Figure 8-10. No options or lower cost alternatives are presented, since it was felt that the basic configuration is already at a low cost and that no additional peripherals are required. This system includes a battery operated computer with a small flat display and keypad. Nonvolatile RAM is used to hold data even when the power is off. The data entry device can be plugged into another system upon return from the field, and the data can then be transferred into a standard data base management system.

E. RATING AND INVENTORY IN THE FIELD (HAND HELD DATA ENTRY DEVICE)

<u>RESPONSE</u>	<u>PROJECTED OEM PRICE IN 1985</u>
<u>PREFERRED</u>	
MILITARIZED KEYPAD	\$ 90
<u>DISPLAY</u>	
<u>PREFERRED</u>	
MILITARIZED SMALL FLAT PANEL (2 ROWS OF 40 CHARS: PRICE IS EXTREMELY SENSITIVE TO NUMBER OF DISPLAY CHARACTERS)	\$ 20
<u>PROCESSING AND STORAGE</u>	
<u>PREFERRED</u>	
8 BIT BATTERY POWERED CPU	\$ 100
16K NONVOLATILE RAM	\$ 50
2 K ROM	\$ 10
PACKAGING AND POWER SUPPLY	\$ 50
	<hr/>
	\$ 320
INTEGRATION (20%)	\$ 64
	<hr/>
	\$ 384

Figure 8-10
Recommended Features and Cost Summary
for the Hand Held Data Entry Device

CHAPTER 9

LOOKING AHEAD

GENERAL CONCLUSIONS FROM THE THREE-PERSON AND SCENARIO ANALYSIS

The old delivery systems have not sufficiently dealt with certain necessary functions. These include:

1. Teacher quality assurance--especially for distributed training involving NCO's and training officers in units.
2. On-the-job training delivery and future assurance.
There are many aspects to this because it has not been possible to perform it adequately with print and voice communications, or with linear audio visual materials. Thus many partial scenarios and sub-scenarios have had to be projected to define how to implement such systems using new technologies.
3. Related to the inadequacy of the current delivery system for on-the-job training and testing is a deficiency in learner quality assurance. Quite aside from the recruiting and enlistment organizations that now exist, improving basic skills is a part of learner quality assurance. It must take place on the job. Basic skills improvement is not well integrated into a total on-the-job and future assurance system. The present Basic Skills Educational Program (BSEP) can be useful, but must be well integrated into on-the-job training in the units.

One of the most critical functions identified in the scenario analysis was that of materials development and improvement. Much progress has been made by the Army in this area. The Army has been a pioneer in Instructional Systems Development (ISD) and distributed training. However, much more needs to be done because the materials development and improvement function is the major driver of both the current problem and its solution. The numerous centers in the Army where authoring of materials takes place now are the source of the paper glut that affects training, maintaining, and general communications. These materials development and distribution centers must be transformed so that they can distribute new optical memories and materials in electronic forms over networks. The authoring system technologies to aid them in so doing is perhaps the most critical development issue that the Army faces. This is the key to improving currently weak delivery systems, teacher quality assurance in the field, on-the-job training and future assurance, and learner quality assurance (through programs like BSEP).

The remainder of this chapter gives more specific conclusions and recommendations. These will be organized under three major types of delivery systems: the electronic delivery system (EIDS) hardware for job training, the SPA's hardware for use in

repair bases and in the field, and the hand-held system. The "issues remaining" discussed below were derived from what the authors perceive as the design areas where the greatest potential benefits exist, or where soft technology issues, if not resolved, introduce the greatest risk of failure. Issues regarding local network communication and storage will not be considered in this chapter, as these matters are not the function of the presentation features study.

CONCLUSIONS AND RECOMMENDATIONS FOR THE ELECTRONIC DELIVERY SYSTEM

Hard Technology Issues

Visual Displays. The following conclusions were drawn regarding visual displays:

- NTSC color video displays are acceptable if they include computer text and graphics. It will be easy to convert existing audio visual materials, but print will require extensive reformatting. After reformatting, NTSC color displays are quite suitable and the cost of reformatting can yield benefits in speed, effectiveness, and interest/motivation if reformatting follows good design principles.
- Medium resolution color graphics is preferred for greater ease and flexibility in reformatting, for greater acceptance and interest, and most importantly, for new options in computer graphics for superior two-dimensional simulations and intelligent interactions. There is a high dollar price for this preferred option by 1985 (about \$3,700) and it will probably be necessary to restrict color graphics to certain two-dimensional simulation applications and in command and control situations where it can be well justified. Medium resolution color displays should be one of the options designed into the modular electronic delivery configuration even if it is not selected for the platform or company level training system.

Audio. Still frame audio on optical memory storage systems (e.g., videodiscs) is an essential for transferring existing TEC and ETV materials to compact job training packages. This is a conclusion from previous studies. This study revealed simply that such a large capacity audio capability will meet all existing requirements and will open new possibilities for increased effectiveness. Thus, there is no need for costly and less effective digitized or synthesized audio where optical memories with still frame audio are used.

Design of the NTSC Videodisc Player. The issue with the greatest significant impact on the eventual cost (after the issue of medium resolution color vs. NTSC video display) is the NTSC videodisc player. The \$800 figure derived in Chapter 8 is a risky figure because it is based on projections for current optical videodisc players. These current players do not have still frame audio. Thus considerable technology development must take place in this

area. Some questions that must be answered are as follows:

- Can photographic media systems be developed that will be more cost-effective than the stamped and aluminized plastic disks?
- Should the format be a spinning disk or a stationary card?
- Should the material be stored in analog format or all-digital format with Digital to Analog converters used to generate both audio and video pictures?
- The resolution of the questions above affects the pre-mastering, mastering and replication technologies considerably. Will local mastering and duplication be made available to the many Army sites where materials development will take place?

The answers to these questions also determines the nature of authoring systems. Authoring systems aimed at producing materials for use on electronic delivery systems that use optical memories cannot be completed and optimized until the hard technology issues are resolved.

Input Devices. The following conclusions and recommendations are made:

- The keypad plus touch panel recommendation will serve adequately, but research and development is needed to define a general keypad usable for all job training packages; or alternatively, a minimum number of more specialized keypads. This research can also consider the elimination of the touch panel by providing cursor control from devices on the keypad.
- Voice input is not required for general job training, but may be specified as a plug-in option when a job requires vocal responses to be trained or hands or eyes to be free.

Authoring Systems for Job Training Materials

With plug-in modules and additional equipment, a variety of authoring systems can be configured for various development needs. It is not possible to specify these precisely at this time because of the remaining soft technology issues.

The Army should pay considerable attention to the design of the authoring station and software for JTP materials. This system, used by contractors in a network accessed by the Army contracting monitor, can provide quality assurance during development.

Soft Technology or Authoring Strategy/Authoring Systems Issues

Because of the large inventory of existing job training materials, and the high cost of electronic displays that minimize reformatting, further research and development on ways to reformat old materials is needed. Before authoring systems can be completely specified, some issues growing out of the new scenarios for the on-the-job and future assurance system must also be solved.

Recommendations for Reformatting. A number of investigations are recommended:

- Still-frame editing is a costly and complex problem now, but adding the editing problem for still frame audio will complicate it even further. TEC and ETV visuals go directly onto NTSC video, but the largely unknown still frame audio problem must be resolved. New authoring systems for still frame audio require research and development.
- Printed materials such as the Army Training Literature Program and the Army Correspondence Course Program will require considerable investigation. The goal is to discover how to reformat at minimum cost and maximum gain in effectiveness, including rate of comprehension and user interest and motivation. This will require the addition of interactive capabilities during the reformatting process.
- Computerized authoring systems with text and graphic processors and prompting systems for the authors need to be developed. Methods for getting the materials into digital form--both text and graphics--and editing these materials need to be investigated and built into the authoring system.

New Issues. The scenarios defined in this and the previous studies have identified a number of areas where considerable further research and development must be conducted. This research is needed to define the most cost effective management and instructional approaches and the best authoring systems to support them. Some of these issues are:

- How to design a management system to implement the Plan for Continuing Individual Training in Units (PCITU) and to extend this to a Plan for Continuing Team Training in Units (PCTTU). Regular electronic delivery systems can be used in a management network to help the trainers and the soldiers schedule training and evaluation in the field and provide a training accountability record.
- How can the NCO's and training officers be trained to train effectively in the field?
- What instructional strategies can be added to old materials in the job training packages, and what new materials can be developed which will utilize the effectiveness of interactions? Interactions can range anywhere from rather inexpensive to very expensive. When is a particular level of intelligence, interactivity and dynamic graphics needed? This study provided much general guidance on this issue, but specific development studies with alternative JIP, SQT, and ARTEP tasks are needed to define new form and style standards.
- How can SQT and SQT practice be integrated into job training? How can 2-D simulation and surrogate travel improve SQT's? Will SQT's disappear as a separate entity as they are integrated fully with training?

- How can ARTEP be integrated into a total on-the-job training program? This requires correlation of group performance scores with individual performance scores.
- How will it be possible to assist in the resource management of training (e.g., as related to the TMAC project)?
- How will it be possible to integrate job aiding in the proper mix with training lessons? Experiment 5 herein showed the increased time effectiveness of a simple job aiding strategy in a cable assembly task. There are instructional strategy issues involved and also political issues. TRADOC is restricted at present in developing job aids. Yet the Army's best interests seem to lie in a much closer integration of job aiding with training materials.

In all of the areas requiring further research described above, a major objective is the design of modular authoring system hardware to leverage the work of the materials developers. Ways to produce the new materials must go hand in hand with the new scenarios, delivery systems, and strategies.

CONCLUSIONS AND REMAINING ISSUES REGARDING MILITARIZED ELECTRONIC DELIVERY SYSTEMS FOR SPA's

Hard Technology or Delivery Systems Conclusions and Issues

Display Devices. A flat panel, bit mapped monochromatic display with medium resolution is quite appropriate. Gray scale is not essential, but reformatting of existed printed SPA's and ETM materials is necessary.

There are some storage media issues remaining in the design of the SPA's delivery system. This study projected a one megabyte bubble memory which holds at least 3.3 SPA's manuals. However, after the storage media report was submitted, a new optical memory card that will hold several megabytes on a pocket-sized card has been announced. This may not have the disadvantages of the optical videodiscs for the SPA's delivery system (reliability and portability) although the update problem would remain. Thus, the various bulk semiconductor memories vs. the optical card memory must be investigated closely. The rapid change in both of these technologies introduces an element of risk in current projections.

Audio. Audio output during maintenance aiding may be quite helpful in some situations but does not appear to be a requirement.

Input Devices. A simple keypad seems quite adequate for the SPA's style maintenance aiding and is also the least expensive. There has, however, been some high level interest (Pentagon) in voice input. Voice input has a number of potential advantages and a number of potential disadvantages, not the least of which is cost. Concept tests in the maintenance aiding context, fully documenting the advantages and disadvantages of voice input vs. specifically designed keypads (perhaps with cursor control) should be initiated.

Soft Technology Issues for SPA's

Reformatting Studies. The specific characteristics of the flat panel to be used must be identified, and its resolution and extent of gray scale must be fully specified. This is being performed in the Technology Based Correlation study of ACTC.

Following this specification traditional reformatting studies need to be conducted to find the most cost effective procedures. These procedures should be implemented into a SPA's authoring system for use by those who will reformat the old SPA's and TM's.

New Authoring R & D. When the issue is the design of displays for electronic delivery rather than converting printed pages, then the design of a SPA's authoring system will have more degrees of freedom. Some issues have to do with whether new materials are produced all-digital from the beginning or not. The prototype for the new electronic SPA's format and the authoring systems for producing the materials should be developed simultaneously.

THE HAND-HELD SYSTEM FOR TRAINING AND INVENTORY ACCOUNTABILITY

Hard Technology Issues

Display. What size should the small flat panel be? How many rows, how many columns? How large a dot matrix? What flat panel technology should it use? How much local memory? While the findings of this study provide guidance, the answer depends on the content of ARTEP, SQT, and inventory applications.

How many functions should the hand-held data entry computer perform:

- . Scoring for SQT and ARTEP?
- . Inventory management?
- . Rapid field calculations?
- . Should this double as a keypad for workstations?

Portable Storage. Should the hand-held unit have a built-in optical or memory card reader?

Input Devices. How many keys should the keypad have? How can they be redefined for multiple uses? Should there be cursor control mechanisms on the keypad?

Soft Technology Issues. The emergence of the hand-held unit represents a critical area for research and development. It is fairly recent in the ACTO series of studies, and it is based on new scenarios for the job training and future assurance scenarios which themselves are quite new. Thus there are many soft technology issues that depend on how the hard technology issues are resolved. For example, how much memory can be contained in the hand-held unit? If an optical card or storage chip card is to be inserted in the hand-held unit the unit can do many more things than if it must only contain built-in semiconductor memories.

However the storage issue is resolved, there is a materials development and programming issue concerning the inventory management protocols, and any other protocols that will be implemented using the same hand-held unit. There are also human factors and

interaction strategy issues that have not yet been defined or investigated.

FINAL COMMENTS

This is not an easy study to summarize. There are many detailed recommendations in the executive summary and in the chapters. These deal with the nuances of when different presentation features are more effective and advantageous. A choice was made to focus this final chapter on those conclusions that are most related to cost-benefits and seem most solid, and those remaining issues which need to be addressed. These issues require resolution before the opportunity of the new electronic and communication technologies can be fully realized by the Army.

One general conclusion is that the technology has progressed far enough to present a variety of attractive alternatives. Further research and development can only lead to more ways to cut costs and increase benefits as the hard technology and soft technology issues are resolved. There do not appear to be any major risk factors in resolving the hard and soft technology issues discussed herein. Thus, the Army's greatest need is decisiveness and commitment in seizing the opportunities for improving force readiness through greatly improved training, maintaining, and communicating, which these new technologies offer.

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APPENDIX A

SOME EFFECTS OF REALISM AND JOB AIDING FOR INSTRUCTION PRESENTED VIA A VIDEODISC

EXPERIMENTS I AND II

The transfer of training material from paper to videodisc requires more than mere transfer; it requires transformation. A printed training manual has the advantage of years of research and development behind it; thus when a new manual is developed, well established guidelines are used. The degree to which these guidelines are transferable to videodisc development is not altogether clear, although great disparity would not be expected. This experiment was designed to test the application to videodisc instruction of training guidelines developed for traditional methods of instruction. The first guideline in question was the relative merit, in terms of accuracy and speed, of realistic photographic versus line drawing instruction. The second question concerned the value of learner instruction prior to use of training material as a job performance aid versus use of the material as a job aid without prior instruction.

The traditional dependent variables for comparing the effectiveness of photographic vs. line drawing instruction have been scores on verbal knowledge of pictures or measures of discrimination of parts of pictures presented on visual/verbal multiple choice tests. The traditional dependent measure of speed for these has been time to complete a criterion task, again usually some kind of visual/verbal test. For instance, research by Borg and Shuller (1979) and Markham (1979) concerning learner identification of tanks after pictorial or line-drawing instruction, as well as pertinent research summarized by Dwyer (1978), indicates that line-drawing instruction and photographic instruction are equally accurate and efficient when learning is measured by scores on multiple choice or identification tests.

However, for all the information in the studies, they do not address these related questions: 1) Do line drawings and photographs yield equivalent visual/verbal test performance in videodisc instruction as they seem to in paper based instruction, 2) Does one picture type yield faster and/or more accurate performance than the other for a psychomotor task as opposed to visual/verbal multiple choice test performance, 3) Does prior instruction improve task and/or test performance speed and accuracy sufficiently to warrant its use in a mechanical procedural training environment, and 4) How well does learning from one picture type transfer to the alternate type of multiple choice test?

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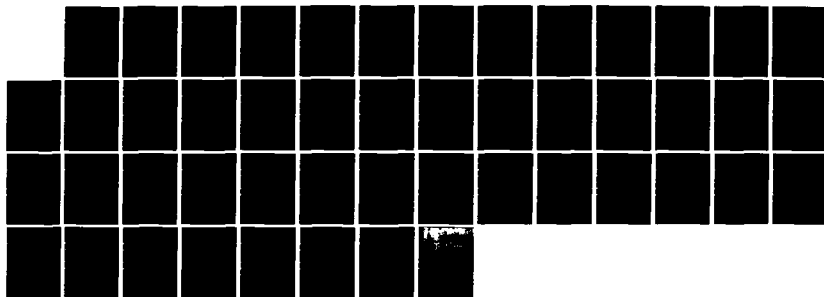
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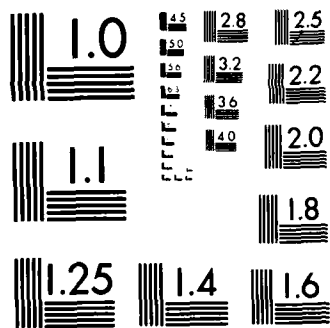
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MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

METHOD

Sample. Sixty students from Orem High School (Orem, UT) comprised the sample for this experiment. Subject ages were distributed as follows: two (3%) were 14 years old, eighteen (30%) were 15, twenty-nine (48%) were 16, eight (13%) were 17, and three (6%) were 18. Sex was distributed thus: fifty-one (85%) were male, nine (15%) were female.

The students were chosen at random from the school population, but participation was voluntary: each student was asked, not required, to participate in a military training experiment involving videodisc technology. There was no incentive offered to attract participants except the opportunity to be excused from class, so personal interest was a factor in subject participation.

Apparatus. There were three stations run by two observers during the experiment. Each was located in a private study carrel at the rear of the Media Center. At each station was a television monitor, a videodisc player, a videodisc, and a box of partially assembled cable adapters.

Two types of monitors were used in the experiment. At two stations were Sony model CVM-1250 Trinitron color receiver/monitors; at the other station was a Panasonic CV-1310V Color Pilot color receiver/monitor; both had nine inch screens.

A Magnavox model VH8000CH01 videodisc player was used at each station. The players were connected to the monitors via the video output jack.

In each player was a Sony videodisc made from a WICAT video tape of U.S. Army Training Manual TM11-5995-208-24&F, in which assembly of coaxial cable adapter CX-10734/G is documented in thirty-eight steps. Five combinations of pictorial, visual, and auditory stimuli were represented on the disc, so the actual technical manual content was reproduced five times. The two combinations used as treatments in the experiment were 1) silent still frames with full color photographic visuals and text explanations developed at WICAT and 2) silent still frames with two color line drawing visuals and text explanations which were direct copies of the technical manual pages. The information contained in the photographic visuals was designed to be virtually identical to that of the line-drawing visuals.

There was also a visual/verbal multiple choice test on the videodisc consisting of fifteen pictures selected from the instruction to represent its domain, each with a question substituted for the text explanation at the bottom.

There were three types of questions asked in the test: 1) what step precedes the step shown in this picture? 2) what step follows the step shown in this picture? and 3) what is missing in this picture for it to be complete? Four alternative answers to each question were printed on a separate answer sheet. The test was reproduced twice, once with photographs and once with line drawings.

The remaining equipment at each station was a group of four communication cable adapters, each in a different stage of assembly, which constituted the four tasks of the performance test. With each cable was a bag of parts which subjects were expected to correctly assemble.

Experimental Design. To answer the four questions listed at the end of the introduction, two sub-experiments were performed. The first three questions were investigated by a 2 X 2 factorial design (see Figure A-1). Experiment 1 involved the factors of picture type and instruction time, with the following levels: photographs and line-drawings for picture type, two minutes and twenty minutes for instruction time. In the job aid condition two minutes were allowed for the subject to quickly become familiar with the layout of the material. Twenty minutes were allowed for the instruction condition.

The dependent variables measured in each cell of this experiment were visual/verbal multiple choice test scores and performance test scores. Two scores were obtained for each test. The first was an accuracy score expressed in raw number of correct items. The maximum possible on the written multiple choice test was 15; the tasks in the performance test contained 19 steps. The second score was a speed score expressed in decimal minutes to complete each test. It should be noted that, though there was necessarily some communication between subject and observer during the performance test, only actual task performance was timed.

To answer question four, another 2 X 2 factorial design was created, with photographic visuals and line drawings instruction as the levels of the first factor and photographs and line drawings test as the levels of the second factor. Figure A-2 presents the design, hereafter known as Experiment 2. The dependent variables were achievement and test time on the verbal/ visual multiple choice.

Procedure. Subjects were seated at a station approximately twenty inches in front of the monitor and within easy reach of the videodisc control buttons. They were then told that the general purpose of the experiment was to see how well the videodisc player could be operated in an environment

FACTOR B INSTRUCTION TIME	2 Minutes	CELL 1 n=14	CELL 2 n=18
	20 Minutes	CELL 4 n=10	CELL 3 n=7
		Photo (1)	Line (2)

Factor A--Picture Type

FIGURE A-1 2x2 factorial design of Experiment One. speed and accuracy measures for visual/verbal and psychomotor tests taken.

FACTOR T TEST PICTURE TYPE	Photo	CELL 1 n=19	CELL 2 n=11
	Line	CELL 4 n=10	CELL 3 n=20
		Photo	Line

Factor I--Instruction Picture Type

FIGURE A-2 2x2 factorial design of Experiment Two. speed and accuracy measures for only visual/verbal test taken.

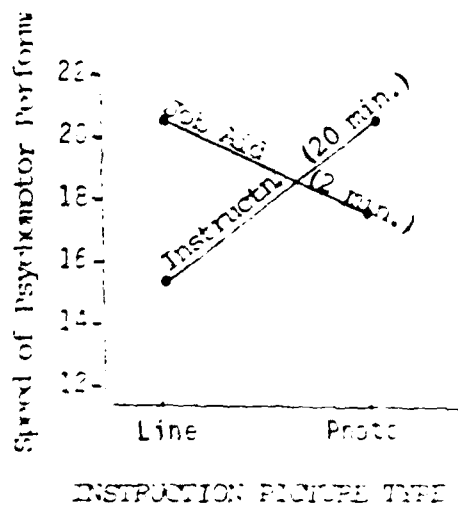


Figure A-3.
Interaction Between
Picture Type and Usage Mode (Job Aid vs.
Instruction) for Speed of
Psychomotor Performance

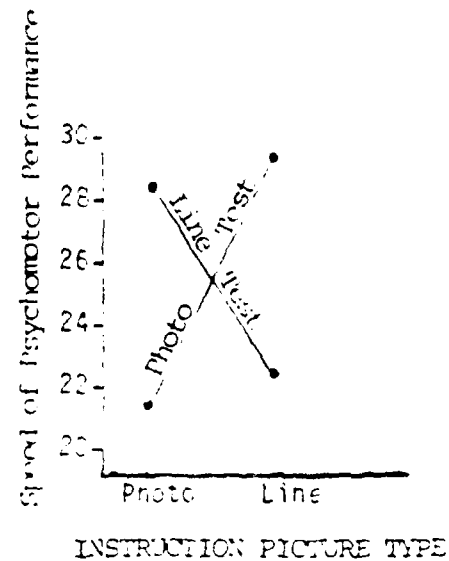


Figure A-4
Interaction Between
Instruction and Test Type for Speed
of Visual/Verbal Performance

traditionally reserved for books.

Subjects who were to receive only two minutes of instruction before beginning the tests were told that they were to take two minutes to familiarize themselves with the general format of a lesson on the videodisc which showed the steps to assemble a military communications cable adapter. They were told that they were not to memorize the instruction but were to use it as a cookbook or maintenance manual, referring to it as often as necessary for correct performance. Subjects were shown how to operate the player, given a short time to experiment with it, and then began their two minute perusal of the instruction.

Subjects who were to receive twenty minutes of instruction before beginning the tests were given the same instructions as those who were to receive only two minutes, with the obvious exception that they were told to take as long as they wanted, up to twenty minutes, to study the instruction. Subjects receiving twenty minute instruction were allowed, like those receiving two minute instruction, to refer back to the content during the tests. There was considerably more variation in the actual study time used by subjects at this level of instruction time, some taking as few as nine minutes and others taking twenty. Study time for each subject at this level was recorded to the nearest .01 minute.

The visual/verbal multiple choice test was administered first, followed by the performance test. The performance test was placed second because, since it was deemed to be the harder of the two tests, it was thought to be to the subjects' advantage to have maximum exposure to the content before they took it. All subjects were administered the tests in the following way.

Subjects, still seated one to a station, were given an answer sheet and directed to write their name, age, sex, and grade in school, and the date in the spaces provided at the top. They then were shown where on the disc the visual/verbal multiple choice test began, and were directed to write down the frame number. They were then shown the relation between the answer sheet and the questions on the monitor, how to get from question to question, and how to get from the test to the instruction and back again. They were given a short time to experiment with these disc manipulations, then were placed at the first question and told that, though they would be timed, they should not hurry but answer each question correctly; then they were told to begin the test. Timing began at this point as well. During the test, subjects were left alone, only communicating with the observer at their request.

When the first test was completed, subjects were given no feedback concerning it, but were immediately introduced to the performance test. They were told that they would now further assemble four partially assembled cable adapters, and that they were free, as on the first test, to refer to the instruction when they desired. After this, subjects were given each cable with its bag of parts one at a time and asked to assemble each correctly. The tasks were given in the order in which the related content appears in the instruction, the first task corresponding to content early in the instruction and the fourth task corresponding to content toward the lesson's end. The following description of subject performance evaluation applies to all four tasks.

When subjects made some purposeful movement, such as pressing a videodisc control button or picking up a cable adapter component, the observer began timing. The observer used an observation sheet printed with the steps in each task to record whether or not each step was correctly performed. The criterion for success on a given step was not that it be done in some particular order but simply that, when the student was finished assembling the adapter, it be correctly assembled. Timing ended when subjects indicated that they were done by holding up the adapter for the observer's inspection or by verbally indicating that they were finished. If subjects who had not attempted the last step of a task asked whether they were finished, they were told no. However, if subjects who had attempted the step but had done it incorrectly asked the same question, they were told yes and the last step in the task was marked wrong.

When both tests were completed, subjects were asked, "How hard did you try on these tests?" Subjects responded by indicating a location on a five point scale, five meaning "very hard" and one meaning "not at all."

RESULTS

The data was analyzed using a two-way analysis of variance. In order to take the unequal cell sizes (shown in figures A-1 and A-2) into account in the analysis, an adjusted ANOVA rather than a sequential ANOVA was used. The model used for experiment one was

$$Y(ij) = A(i) + B(j) + AB(ij) + e$$

where factor A was picture type and factor B was instruction time, both factors being fixed. The model for experiment two was

$$Y(ij) = T(i) + I(j) + TI(ij) + e$$

where factor T was test picture type and factor I was instruction picture type. Again, both factors were fixed. Alpha was set at .05 for both experiments. Each experiment will be discussed in further detail below.

Experiment One. Tables A-1 and A-2 present means and standard deviations for the factors of interest. Table A-3 presents the Analysis of Variance results. The results of this experiment shed some light on questions one through three (listed at the end of the introduction). Generally speaking, picture type seemed to have no effect on either performance speed or accuracy. This was true of both the multiple choice test and the psychomotor test, although there was an exception which will be discussed below. Prior instruction seemed to affect visual/verbal test performance time, but accuracy scores remained roughly equivalent across both levels of this factor. There was evidently no effect on either speed or accuracy of psychomotor performance. The statistics supporting these generalizations are given below.

Picture type had no effect on speed or accuracy in either criterion task. The F-value from the test of effect of picture type on visual/verbal test speed was 0.03, non-significant when compared to the table value of 4.04 (df 1,56). The F-value from the same test applied to visual/verbal accuracy was also non-significant: 0.19. The F-value from the test of effect of picture type (factor A in the model) on psychomotor performance speed was 0.39, well below the table value of 4.08 indicated by the degrees of freedom (df 1,45). The F-value from this test on psychomotor performance accuracy was 1.14, again well below this rejection region. Thus there was no apparant effect on either dimension of visual/verbal or psychomotor performance by picture type.

There was, however, an exception to these findings. This exception was a significant interaction between the factors on the speed measure. An F-value of 4.94 was found for a table value of 4.08. Subjects who received twenty minute instruction and line-drawings completed the psychomotor test more quickly than subjects in any of the other three cells. The next fastest time was for two minute instruction with photographs; the cell combining twenty minute instruction with photographs was virtually equal to the cell combining two minute instruction and line-drawings. Figure A-3 presents the interaction graphically.

The presence or absence of prior instruction affected neither speed nor accuracy in psychomotor performance, nor did it affect accuracy of performance on the visual/verbal test. The F-values for effect of prior instruction on psychomotor speed and accuracy were 0.43 and 0.25 respectively, and both were below the table value of

Table A-1

MEANS AND STANDARD DEVIATION FOR SPEED AND ACCURACY OF
VISUAL/VERBAL AND PSYCHOMOTOR PERFORMANCE
IN EXPERIMENT ONE

	FACTOR A PICTURE TYPE				FACTOR B INSTRUCTION TIME			
	PHOTO		LINE		2 MIN.		20 MIN.	
	\bar{X}	SD	\bar{X}	SD	\bar{X}	SD	\bar{X}	SD
Vis/Verb Speed	23.33	9.70	24.44	8.67	26.01	8.13	18.58	9.58
Vis/Verb Accuracy	10.20	3.07	10.29	2.45	10.23	2.83	10.29	2.59
Psychomotor Speed	18.51	6.08	18.80	8.25	19.03	7.40	17.95	6.97
Psychomotor Accuracy	15.25	3.09	14.84	2.30	15.12	2.57	14.88	2.99

Table A-2

INTERACTION MEANS AND STANDARD DEVIATION FOR SPEED AND
ACCURACY OF VISUAL/VERBAL AND PSYCHOMOTOR PERFORMANCE
IN EXPERIMENT ONE

	PHOTO 2 MIN.		PHOTO 20 MIN.		LINE 2 MIN.		LINE 20 MIN.	
	\bar{X}	SD	\bar{X}	SD	\bar{X}	SD	\bar{X}	SD
Vis/Verb Speed	25.40	9.01	19.41	10.21	26.50	7.52	17.39	9.16
Vis/Verb Accuracy	10.36	3.11	9.90	3.14	10.12	2.65	10.85	1.5
Psychomotor Speed	17.11	4.56	20.46	7.57	20.52	8.86	14.36	4.2
Psychomotor Accuracy	14.85	3.18	15.80	3.04	15.33	2.05	13.57	2.57

Table A-3

ADJUSTED TWO WAY-ANOVA TABLES FOR SPEED AND ACCURACY
OF VISUAL/VERBAL AND PSYCHOMOTOR PERFORMANCE
IN EXPERIMENT ONE

	SOURCE	df	MS	F
Visual/ Verbal Test Speed	Picture Type	1	2.52	0.03
	Instruction Time	1	676.15	9.00*
	Interaction	1	29.05	0.38
	Error	56	75.11	
Visual/ Verbal Test Accuracy	Picture Type	1	1.51	0.19
	Instruction Time	1	0.20	0.02
	Interaction	1	4.27	0.54
	Error	56	7.87	
Psycho- Motor Speed	Picture Type	1	19.58	0.39
	Instruction Time	1	21.35	0.43
	Interaction	1	244.90	4.93*
	Error	45	49.58	
Psycho- Motor Accuracy	Picture Type	1	8.30	1.14
	Instruction Time	1	1.81	0.24
	Interaction	1	19.78	2.72
	Error	45	7.26	

*= $\alpha < .05$

4.08 (df 1,45) in both cases. The F-value for this same effect on visual/verbal accuracy was 0.026, which was also under the table value of 4.04 (df 1,56).

Conversely, there was a significant F-value found for the test of effect of prior instruction on visual/verbal performance speed. The table value was 4.08, as explained above, and the F-statistic was 9.00. As might be expected, subjects receiving twenty minutes of instruction took less time than those receiving only two. However, there is an interesting corollary to this:

Another F-test was performed on the time it took subjects to complete both instruction and test in each of the two cells. Again the F-value was significant (13.087 compared to a table value of 4.04), but in the opposite direction. Considering instruction time as well as test time, subjects receiving twenty minutes of instruction took longer than those receiving only two. This result is particularly noteworthy in light of the report above that there was no difference in accuracy between the cells. Further analysis of the data revealed an important result in the affective domain:

Tables A-4 and A-5 present the means and significance test results for the data on ratings of task difficulty. The mean perception of task difficulty for students receiving twenty minute instruction was compared to the same mean for students receiving two minute instruction, and an F-value of 4.374 was found (the table value was again 4.04). Subjects who received two minute instruction, though they performed as accurately as their twenty minute counterparts on the visual/verbal test and as accurately and quickly on the psychomotor test, nevertheless rated their total experience as more difficult.

Experiment Two. The research question for this experiment was to test the interaction of instruction picture type (pictures or line drawings) and test picture type (pictures or line drawings) As noted in the experimental design section, the dependent variables of achievement and time were studied in this experiment.

Table A-6 presents the means for Experiment Two, while Table A-7 presents the significance test results. The statistics of interest in this experiment were those testing the interactions between factors. All other tests simply duplicated those performed on factor A in experiment one: tests on the interactions, on the other hand, checked the learning transfer from one level of instruction to the opposite level of test.

Table A-4

MEANS AND STANDARD DEVIATION FOR SUM OF INSTRUCTION TIME
AND TEST TIME, AND MEANS AND STANDARD DEVIATION FOR
PERCEPTION OF TASK DIFFICULTY FOR EACH LEVEL OF FACTOR B
(INSTRUCTION TIME) IN EXPERIMENT ONE

	2 MIN.		20 MIN.	
	\bar{X}	S D	\bar{X}	S D
Summed Instruction and Test Time	28.21	8.03	36.84	8.25
Perception of Task Difficulty	4.14	0.66	3.78	0.80

Table A-5

ADJUSTED TWO-WAY ANOVA TABLES FOR SUMMED INSTRUCTION TIME
AND TEST TIME, AND PERCEPTION OF TASK DIFFICULTY FOR
FACTOR B (INSTRUCTION TIME) IN EXPERIMENT ONE

SOURCE	df	MS	F
Summed Instruction and Test Time	1	884.37	13.06
Error	56	67.57	
Perception of Task Difficulty	1	2.13	4.37
Error	37	2.48	

Table A-6

MEANS AND STANDARD DEVIATION OF FACTOR INTERACTION ON
SPEED AND ACCURACY MEASURES IN EXPERIMENT TWO

	SPEED		ACCURACY	
	\bar{X}	SD	\bar{X}	SD
Photo Instruction.	20.52	8.51	10.10	3.26
Photo Test Line				
Instruction.	21.87	8.10	10.50	2.50
Line Test				
Photo Instruction.	28.68	9.96	10.40	2.83
Line Test				
Line Instruction.	29.12	7.96	9.90	2.42
Photo Test				

Table A-7

ADJUSTED TWO-WAY ANOVA TABLES FOR FACTOR INTERACTION
ON SPEED AND ACCURACY MEASURES IN EXPERIMENT TWO

	SOURCE	df	MS	F
Speed	Instruction	1	10.91	0.14
	Test	1	2.83	0.03
	Interaction	1	810.36	11.12 *
	Error	56	72.86	
Accuracy	Instruction	1	0.03	0.00
	Test	1	2.67	0.33
	Interaction	1	0.29	0.03
	Error	56	7.89	

The interaction between factors on the accuracy measure yielded a non-significant F-value of 0.04, the table value being 4.04 (dft=1, dfe=56). However, the interaction on the speed measure was a significant 11.12. Subjects who received one picture type in their instruction and the other in their test took longer to complete the test than those who received the same picture type in both. Tables A-6 presents the means and standard deviations for this interaction. Figure A-4 presents the interaction graphically.

DISCUSSION

Interpretation of the results described above will be more a function of the psychomotor test findings than of the visual/verbal test findings. This is because the type of training which the videodisc lesson used in the experiments typifies, is that associated with mechanical/procedural tasks. All conclusions in this section should be read with that in mind. Findings of each experiment will be interpreted separately below.

Experiment One. The questions to be answered here were, again,

- (1) Line drawings and photographs are equally instructive in paper based training when learning is measured by visual/verbal tests; are they equal according to this criterion in videodisc training as well?
- (2) Are line drawings and photographs equally instructive (in videodisc training) when learning is measured by psychomotor tests?
- (3) Does videodisc instruction prior to task performance improve learning, in comparison to a job aid, sufficiently to warrant its use in the mechanical/procedural training environment?

The results above indicated that the answer to question one is "yes, photographs and line-drawings are equally instructive in videodisc training when learning is self-paced and measured by a visual/verbal test." This means that line drawings and photographs are equally powerful in videodisc instruction, as well as in paper based instruction, when learning is measured by visual/verbal tests.

Question two can be answered similarly. The lack of statistical difference between speed or accuracy psychomotor scores of subjects receiving photographic instruction and those of subjects receiving line-drawing instruction implies that photographs have no more effect on psychomotor learning than do line drawings.

Question three is less clear-cut. On the one hand, subjects receiving twenty minute instruction completed the visual/verbal tests more quickly than those receiving two minutes. On the other hand, however, subjects receiving two minutes of instruction took less time overall than their twenty minute counterparts. If this were all the relevant information in the experiment, a case could be made for eliminating instruction on the basis of cost-effectiveness: two-minute subjects performed as accurately as twenty-minute subjects, and did it faster overall.

However, there is more to consider. Subjects who received twenty minutes of instruction felt more comfortable with the tasks than those who received only two minutes. Also, picture type, just dismissed as of insignificant effect, surprisingly contributes to a significant interaction of instruction time on speed of psychomotor test completion. Each of these observations is discussed separately below.

Subjects receiving twenty minutes of instruction did indeed report significantly more ease in task completion than those who received two minutes. However, the size of the difference is only 6% of the possible range of opinion. In other words, twenty-minute subjects felt they had, collectively, tried a little less than "hard" (3.8 on a scale of 5) and two-minute subjects felt they had, on the whole, tried a little more than "hard" (4.1 on a scale of 5). Thus, while the difference shown is probably extant in the population of which the subjects were a sample, it likely is of little practical importance.

This argument cannot be used on the interaction though; the difference between its maximum and minimum means is as great as any in the experiment. Discussion with the observers who actually collected the data, however, prompted this relevant remembrance: over half the subjects had, after completing the experiment, briefly viewed the treatment they did not receive, and a number had commented that, although the photographs were "realistic," the line-drawings were "clearer." The observers took this to mean that the line-drawings had more information in them than the photographs.

Review of the lessons revealed that there were, indeed, two recognizable differences in message design, if not in content: a) the line-drawings had arrows or other symbols which were missing in the photographs, to indicate

the movement of a part being placed onto the cable adapter; and b) the line- drawings contained enlargements, again missing in the photographs, of parts too small to be drawn in detail at the scale of the rest of the picture. (Note that the NTSC standard resolution of the TV monitors did not allow the photographs any more accuracy than the drawings). The photographs however, provided a better picture of the relative size and position of the components than did the drawings.

These aspects of the line drawings could have caused confusion in subjects' minds when they were confronted with drawings criss-crossed with arrows and lines and partially covered with enlargements. This may have been a factor in the slower speed of psychomotor test completion by subjects with two minute instruction. Conversely, these same aspects could have clarified the information to students receiving twenty minute instruction, since there was more information represented per picture and the subjects could process it relatively at their leisure.

This idea, along with the lack of evidence elsewhere in the results supporting other hypotheses, suggests that the interaction may have been an artifact of the materials rather than a bona fide characteristic of the independent variables.

With all this in mind, there is some evidence that, in a mechanical/procedural training environment, guiding trainees through the actual procedures by use of the videodisc may be just as effective as and more efficient than giving them a long period of instruction before letting them get their hands on the equipment.

Experiment Two. The question here was whether learning from one picture type will transfer to a visual/verbal test of the other type as well as to one of the same type. The answer is straightforward: while accuracy was not affected, speed was. Tests of the same type as the instruction were completed more quickly than those of the opposite type. Thus the conclusion from experiment two is that pictorial training material should be of the same picture type as that used in the test.

APPENDIX B

THE LEGIBILITY OF LINE DRAWINGS AND ALPHANUMERICS ON NTSC STANDARD TELEVISION

EXPERIMENT III

This section reports an experiment performed to define the size of visual reduction at which line drawings, numbers, and print typical of military training material become illegible when displayed on NTSC standard color TV. These experiments were performed as part of research aimed at recommending to the Army Communicative Technology Office optimum specifications for electronic presentation of training and maintenance material.

The first component was designed to define the sizes at which actual performance was best. The second component was designed to define the sizes which were preferred. Five sizes of line drawings and five corresponding sizes of text were presented. The smaller drawings and text were expected to yield both poorer performance data and poorer preference data since small characters do not resolve as well as large ones. The real question therefore was this: Specifically which change in size results in unacceptable video presentation of material?

METHOD

The procedures differed for each component, so each will be described separately; however, subjects and apparatus were identical for the experiments and hence will be described together. Size and type of graphic were the independent variables of interest. The dependent variables were proportion correct and legibility ratings.

Subjects. Two groups of subjects participated in the study: Forty Brigham Young University (Provo, Utah) students solicited by classroom announcement or public advertisement and remunerated with a movie theater pass comprised one sample; seven members of the Pleasant Grove (Utah) Petroleum Pipelines unit of the Army Reserve who were asked to participate by their C.O. comprised the other sample.

In the BYU group, 28 (70%) of the participants were male; of those, 26 (93% of the males, 65% of the sample) were students between the ages of eighteen and twenty-five and 2 (5% of the males) were faculty members between the ages of thirty and fifty. One young man was French and one

was Pakistani. All twelve female participants (30% of the sample) were students between eighteen and twenty-five years old. None of them were non-native.

In the Army Reserve group, five (71%) of the seven participants were male; all of them were between thirty and fifty years old. Of the two female participants (29% of the sample) one was in the age category of eighteen to twenty-five years old and the other was in the age category of thirty to fifty years old. None of the Reservists was non-native.

Apparatus. The drawings and text were recorded on an optical videodisc mastered from a 1 inch video tape produced by WICAT. The disc was played on a Discovision Model PR-7820 videodisc player. The player was connected via its video output jack to a model CVM-1250 Sony Trinitron color receiver/monitor. This system operates on the NTSC standard of 525 raster scan lines with a 2:1 interlace refresh pattern at a bandwidth of 4.26 megahertz; it yields a vertical resolution of 225 and a horizontal resolution of 350 as read from a RETMA EIA resolution chart. When response times were measured, a quartz chronograph stopwatch was used.

Materials. Seven types of stimuli were used in the experiments: 1) aircraft altimeters, 2) aircraft horizontal-vertical situation indicators, 3) aircraft heading indicators, 4) voltmeters, 5) aircraft control panels, 6) passages of text, and 7) flowcharts. For the first four types, subjects were asked to read a number indicated by the needle or pointer on the instrument. Subjects were asked to rate the fifth type (control panels) on the legibility of knob setting labels. For types six and seven, subjects were simply asked to read the text. Each of these types was presented at five sizes, chosen to present a range of legibility from easy to impossible.

Size was measured by height of characters in TV scan lines. Table B-1 presents the seven types of stimulus materials and five sizes of alphanumerics. Note that the altimeter is larger than other materials at each relative size, and that text was also somewhat larger. The altimeter contained two distinct sizes of text. Subjects were explicitly directed and trained to rate the larger size, and it is this size which appears in Table B-1.

Subjects participated one at a time. Each subject was seated 27 inches from the TV screen, but was told to move closer or farther away as comfort dictated. The subject was asked to read four dials (stimulus types 1 through 4) at various readings and sizes. Before the stimuli were presented, an example of each dial at its largest size was shown and subjects were told how to read

TABLE B-1
HEIGHT OF PRIMARY ALPHANUMERICS (EXPRESSED IN TV SCAN LINES)
AT EACH SIZE FOR EACH STIMULUS

STIMULUS	SIZE 1	SIZE 2	SIZE 3	SIZE 4	SIZE 5
1. Altimeter (ALT)	15	18	21	26	30
2. Horizontal- vertical Indicator (HVI)	4	5	8	9	13
3. Heading Indicator (HI)	4	5	6	8	12
4. Voltmeter (VM)	4	6	8	9	14
5. Control Panel (CP)	4	5	6	8	10
6. Text (T)	6	9	10	13	18
7. Flowchart (FC)	4	5	6	8	12

it. When the subject indicated confidence in reading each dial, a randomized sequence of dials at various sizes and readings was presented. The time it took the subject to read each dial was measured and recorded. Each answer was recorded as correct or incorrect as well. This component usually took about five minutes.

To evaluate subjective preferences for different display sizes, each participant was shown all seven stimuli at every size and reading. Stimuli were presented in alternating order from large to small and then small to large. Subjects gave each picture a legibility rating on a scale of 5 to 1, 5 being readable but too big, 4 being ideal, 3 being readable but too small, 2 being only partially readable, and 1 being unreadable. Subjects were told that a) they need observe no particular order in their ratings even though the stimuli would be presented in large to small order, and b) they should rate each picture according to how well they could read it and not according to whether or not they knew what it said (since they always saw the largest size first). Each stimulus was then presented and rated. This component usually took about ten minutes for each presentation order.

RESULTS

Table B-2 presents the average response times and proportion correct for each display dial size for each sample population. This table shows that response time and errors increase as the display size decreases. Display size 4 appeared to be optimum size for lower response time and fewest errors.

Figure B-1 presents the legibility ratings for each type of material at each size. The decrease in legibility rating is basically linear for decreasing size, in the range selected. Note, however, that the altimeter at 15 scan lines size receives only a modest rating, while other types of indicators at 15 scan lines receive a very high rating. This may be due to subjects rating the smaller text in the altimeter graphic. Table B-3 presents the mean percent at each preference for each size. A sharp break occurs for sizes 4 and 5 between ratings of "Readable but small" and "Ideal."

DISCUSSION

Figure B-2 presents an abstracted relationship between character height in scan lines and preference rating. This curve fits the data rather well, and corroborates related studies which find that 10 to 12 TV

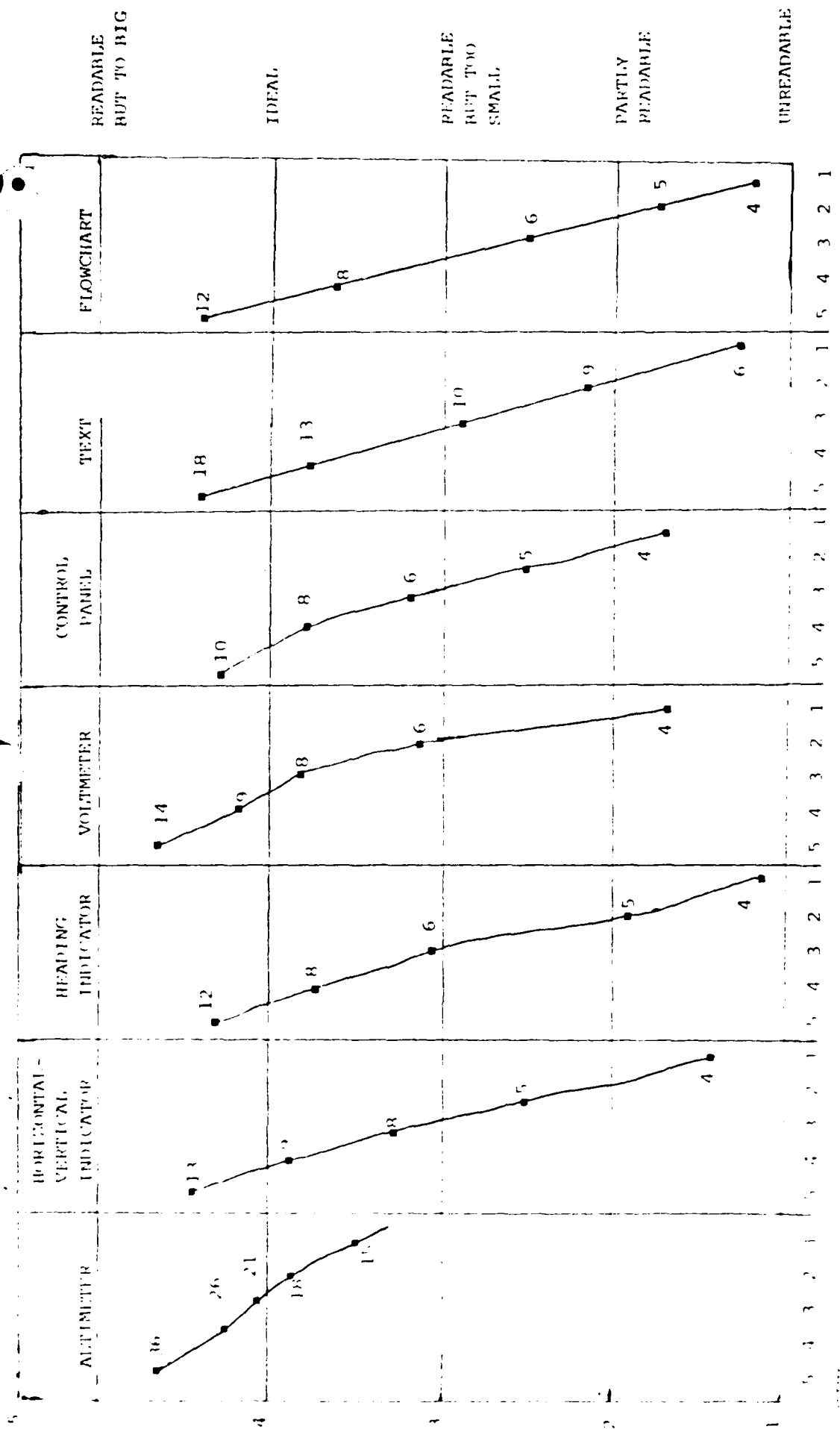


FIGURE R-1
MEAN LEGIBILITY RATINGS BY SIZE FOR EACH
STIMULUS TYPE
(CHARACTER HEIGHT IN TV LINES NOTED BESIDE EACH MEAN)

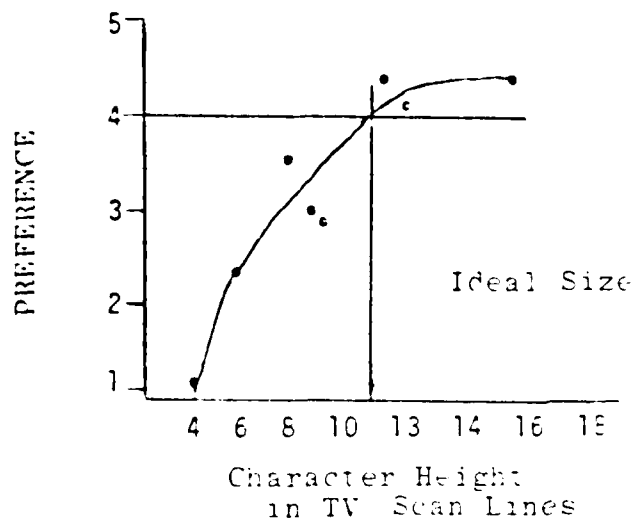


FIGURE B-2
Mean Preference by Character Height for the Horizontal-Vertical Indicator, Heading Indicator, Text, and Flowchart.

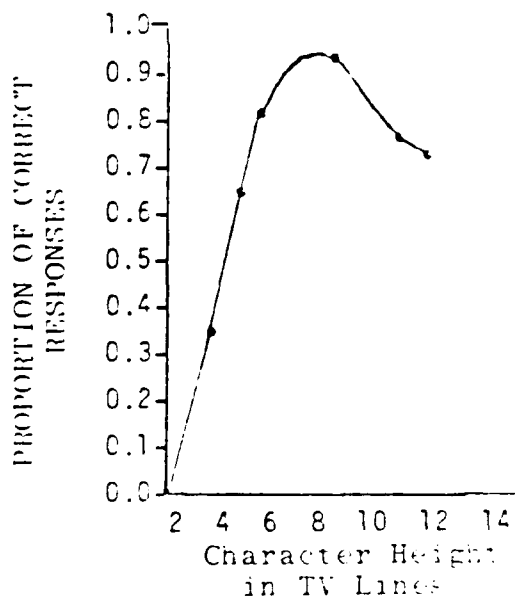


FIGURE B-3
Mean Proportion of Correct Response by Character Height in TV Lines for the Horizontal-Vertical Indicator and Heading Indicator.

Table B-2
MEAN RESPONSE TIME AND PROPORTION CORRECT
BY DISPLAY DIAL SIZE

		College (N=40)		Army Reserve (N=7)	
		Response Time	Proportion Correct	Response Time	Proportion Correct
Small					
	1	10.53	.67	10.48	.52
Display	2	6.49	.79	10.42	.83
Size	3	4.80	.94	8.35	.93
	4	4.71	.96	6.05	.92
	5	4.91	.87	7.01	1.00
Large					

scan lines is an excellent choice for legibility. Figure B-3 presents a similar curve for proportion of correct responses in relation to character height. Note that size can become so large that subjects begin to make more errors.

This research motivates some tentative conclusions: Text and graphic elements should be measured in scan lines and should be at least 10 lines in height. Materials development should generally ensure that where type sizes are mixed, that all are at least 10 scan lines high and that rarely are very large fonts (above 14 to 16 scan lines) used for text.

TABLE B-3
Percent of Each Preference Rating
at Each Size

SIZE						
	Small	1	2	3	4	5 Large
Unreadable	1	59.6	17.9	2.0	0.2	0.0
Partly Readable	2	19.4	35.0	14.3	1.7	0.1
Readable but small	3	14.6	31.1	40.0	18.0	0.8
Ideal	4	6.4	15.5	40.1	70.1	53.0
Readable but large	5	0.03	0.5	3.0	10.0	46.1

APPENDIX C

EXPERIMENT 4 RESOLUTION REQUIREMENTS FOR TRANSFERRING PRINTED MATERIALS TO AN ELECTRONIC DELIVERY SYSTEM

Electronic delivery systems must be capable of presenting a wide variety of visual and text displays which are currently available in paper text and textbook form. The conversion of print materials to electronic form may be accomplished through photographic reproduction or several alternative reformatting approaches. Photographic reproductions requires a television camera, a video storage system and an electronic display device (CRT). Reformatting of visuals and text for electronic displays can be done through either digital scanning and software reformatting, or video character generator reformatting. Using a video character generator WICAT Systems in Orem, Utah has demonstrated the feasibility of reformatting lessons and courses from technical manuals to electronic form for videodisc display. The Illinois Institute of Technology Research Institute has been conducting research on digital scanning and software reformatting of visual and text information. Both projects are supported by the Army Communicative Technology Office (ACTO). Photographic reproduction of visual and text information for use with electronic displays was the focus of the present experiment.

The study was designed to identify the video bandwidth and scan line rates necessary for effectively presenting visual and text information following a photographic reproduction process. Current research indicates that the visibility and legibility of a CRT display is a function of both the video bandwidth signal and the scan line rate (Shurtleff, 1980; Snyder, 1980; Sherr, 1979; Task, 1979). Erickson (1978), Snyder (1974), and Shurtleff (1980) specifically propose that the use of medium and high resolution line rates (greater than 525 scan lines) can increase the display image quality and improve viewer performances.

Existing research also shows that standard NTSC displays (525 lines) have a line rate resolution that is less than or equal to the resolution of the printed page (Stewart, 1976).

The present study investigated the raster scan line rates and video bandwidth settings which were necessary for effective electronic display of video and text information. Three raster scan line rates and five bandwidth settings were used.

Method

Subjects. Two samples of subjects were used for this experiment. The first sample consisted of 59 students and/or faculty at Brigham Young University. The first sample included 38 male and 21 female subjects with an average age of 22 years. All subjects had normal or corrected 20/20 vision. The second sample consisted of 12 Army Reserve personnel from the Pleasant Grove Army Reserve Unit in Utah. The second sample included 10 male and 2 female subjects. All of these subjects had normal or corrected 20/20 vision.

Apparatus. A closed-circuit television system was used for the study. The system included a Cohu 7120 High-Resolution vidicon camera and a Conrac QQA 17/c monochrome video monitor. The bandwidth and scan line rate were controlled from a Cohu 7932 High-Resolution Monochrome Television Camera Control Unit. Scan line rates of 525, 945 and 1225 lines were produced using both camera and monitor controls.

Alternative bandwidth settings were presented by interchanging the components of the Bandpass Filter Assembly on the Video Processor circuit board. The experiment involved five bandwidth settings, of 8, 12, 16, 20, and 32 MHz. When the bandwidth filters and coils were received we contacted the manufacturers to check the codes for the bandwidth filters and coils. The codes checked out for all components except for one electronic coil for use with the 12 MHz filter. The company had no record of the codes used on the coil. The coil was used in the experiment as though it was the correct coil.

Besides the available lighting that each experimental room provided, two floodlamps with soft-white, 100 watt light bulbs were used to produce an ambient light of five footcandles at the target surface.

Stimuli. Five experimental stimuli were selected from military training handbooks. A brief description of each stimulus is given below:

- a. Black and white photographs of a small military weapon system: Suitcase Sagger Antitank Guided Missile: TRADOC Pam 71-9, p. 3-30-7.
- b. Page of standard text: Mil-M-38784A, p. 37.
- c. Gray scale-coded flow diagram: MIL-MD-IC-63038-1, p. 16/3.

- d. Page of text with alternative type fonts: Preparing Text For Printing, MIL-HDBK-63038-1, p. 15/20.
- e. Large Photograph: Telfare Device (Machine gun strap on mount); TRADOC Pam 71-9, p. 3-17-15.

The TV camera was focused on each stimulus so that the full page appeared on the TV monitor. Because of the ratio of length to width needed for presentation of 8½" x 11" displays, the monitor was placed on its side. The standard 3:4 monitor aspect ratio was thus changed to a 4 to 3 aspect ratio.

Experimental Design. The subjects viewed each stimulus described above at bandwidths of 8, 12, 16, 20, and 32 MHz; and at scan rates of 525, 945, and 1225 lines. The variables of the system were combined into a 5 (bandwidth) x 3 (scan rate) x 5 (stimulus) matrix to produce 75 different experimental conditions for each subject.

For the first sample, the order of bandwidth presentation was randomized, while scan rate was not. The scan rate for each bandwidth was incremented from 525 to 945 to 1225 lines. For the second sample, the order of both bandwidth setting and scan rate were randomized for each group of subjects. The order of presentation for the five stimuli, however, did not vary for either sample. The presentation order for each stimulus at each setting was from stimulus (a) to stimulus (e) in descending order.

Procedure. The subjects were seated in groups of two in front of the TV monitor which rested on a table directly before them. The monitor was placed at approximately 28 in. (70 cm) viewing distance (as suggested by Bean, in press).

Each group of subjects was introduced formally to the system and briefed as to the objective of the experiment. The subjects were then shown the five stimuli to be used during the experiment and were told to rate the quality of the reproduced image (versus the original) each time it appeared on the TV monitor. Subjects were asked to mark their responses according to the following scale:

- 7 Excellent. The picture on the screen is of the same quality as the original.
- 6 Very good. The picture is very clear, but not quite as clear as the original.
- 5 Good. The picture quality has diminished somewhat but is still more than adequate.
- 4 Fair. The picture is of adequate quality.
- 3 Poor. Picture quality has diminished to below-acceptable standards.

2 Very poor. The picture is no longer fully legible and is uncomfortable to watch.

1 Unacceptable. The picture quality is not acceptable.

Subjects were next shown each of the stimulus materials in paper form. The subjects were told that they should rate the overall image quality of each display presented on the television display.

In a typical test trial, one of the five stimuli would appear on the TV monitor under one bandwidth/scan rate condition. Each subject was allowed to view the picture as long as necessary and would then circle the image quality rating corresponding to that stimulus and that setting. The experimenter then removed the picture from the monitor, leaving a blank screen, and inserted the next stimulus. After all five stimuli had been seen under one bandwidth/scan rate combination, the experimenter changed either the scan rate or bandwidth in accord with the experimental design.

During the test run, subjects were permitted to ask questions concerning the procedure; however, only those questions whose answers were not felt to prejudice the outcome of the experiment were dealt with immediately.

Results

Descriptive statistics and a three way analysis of variance were calculated for the major factors of bandwidth, scan line rate, and research samples. For generalizability purposes all factors were assumed to be random factors. The dependent variables were the legibility ratings for the five stimulus displays, plus a sixth summed scale across the five displays. The RUMMAGE statistical package was used for analysis and an adjusted rather than sequential analysis of variance was calculated where each term was tested last in the model (Scott, Bryce, and Carter, 1980).

Interaction plots of means and F statistics were examined for each of the five stimulus displays and the summed scale. The results from the summed scale are presented in detail below and the results from the five stimulus displays are summarized to identify general patterns of results. The same general patterns of results were found on the summed scale as on the five subscores.

Five major patterns emerged from the analysis of legibility ratings for the five stimulus displays. First, the ratings for the 525 line rate were significantly and consistently lower than ratings for 945 lines and 1225 lines. Second, the ratings for the 20 and 32 MHz bandwidths tended to be higher than the ratings for other bandwidth settings. Third, the Army Reserve population ratings were consistently higher than the ratings of the college student and faculty sample. Fourth, the three photograph and line drawing stimuli had higher legibility ratings than the two text pages. Fifth, there was a pronounced drop in legibility ratings for the 12 MHz bandwidth setting.

Table C-1 presents the means and standard deviations for the summed scale; Table C-2 presents the three way analysis of variance results.

Table C-2 shows significant effects for the factors of bandwidth, line rate, and subject group. Figure C-1 presents a plot of the cell means for each bandwidth line rate, and subject group. These plots show that the 525 line rate was less legible than the 945 and 1225 line rates. The 20 and 32 MHz bandwidths were rated highest for legibility. The reserve group ratings were generally higher at all levels than the college student and faculty sample. Table C-3 provides the analysis of variance table across the five stimulus displays. This table shows a significant effect for stimulus displays ($F_{4, 1064} = 153$). Table C-4 presents the relevant means and standard deviations. This table shows that the photographs were judged as more legible than text pages.

The five stimulus displays and the summed scale also showed a slight drop in legibility at 12 MHz. As discussed above this result may have been due to an out of tolerance electronic coil in the 12 MHz bandwidth filter assembly. There was also a slight drop in legibility at 32 MHz. Since the monitor was designed to run up to 30 MHz, the 32 MHz filter may have been incompatible with the 30 MHz monitor electronics.

Discussion

The above results indicate that the standard NTSC 525 scan line system does not provide sufficient resolution for effective display of full page graphics and text from technical manuals. The above result was more pronounced for the text pages than for the photographs and graphics pages. Photographs and graphics pages were rated much higher at all settings than were text pages. This suggests that text to CRT conversion would require higher resolution than visual graphics conversion. A scan rate above 525 lines is needed for full text page to electronic raster scan display conversion. The 945 line rate used in the present experiment did provide sufficient text and graphics image quality.

Table C-1
Means and Standard Deviations (in Parentheses)

College Group Bandwidth MHz						
	6	8	12	20	32	TOTALS
525	3.2	2.6	2.5	2.4	2.6	2.7
	(.13)	(.14)	(.14)	(.14)	(.14)	(.92)
945	4.8	4.4	4.3	5.0	4.7	4.6
	(.14)	(.14)	(.14)	(.14)	(.14)	(1.25)
1225	4.5	4.1	3.7	4.5	4.7	
	(.14)	(.14)	(.14)	(.14)	(.14)	(1.19)
TOTALS	4.1	3.7	3.5	4.0	4.0	
	(1.26)	(1.34)	(1.36)	(1.53)	(1.54)	

Army Reserve Group Bandwidth MHz						
	6	8	12	20	32	TOTALS
LINE RATE	525	3.8 (.31)	3.2 (.31)	3.0 (.31)	3.8 (.31)	3.6 (.31) 3.5 (.86)
	945	5.7 (.31)	4.7 (.31)	4.7 (.31)	5.9 (.31)	5.2 (.31) 5.3 (.99)
	1225	5.7 (.31)	5.0 (.31)	4.1 (.31)	5.7 (.31)	5.8 (.31) 5.5 (.95)
TOTALS	5.1 (1.16)	4.3 (1.13)	4.0 (1.15)	5.2 (1.22)	4.9 (1.22)	

Table C-2
Adjusted Analysis of Variance Table

<u>SOURCE</u>	<u>DF</u>	<u>SUM OF SQUARES</u>	<u>MEAN SQUARES</u>	<u>F</u>
Bandwidth (A)	4	69.28	17.32	15.39*
Line Rate (B)	2	428.11	214.06	190.14*
AB	8	17.26	2.16	1.92
Subject Group (C)	1	95.35	95.34	84.70*
AC	4	10.14	2.53	2.25
BC	2	2.74	1.37	1.22
ABC	8	3.23	0.40	.36
Error	1035	1165.16	1.13	

* $\alpha < .05$

Table C-3
Analysis of Variance Across Stimulus Displays

<u>Source</u>	<u>df</u>	<u>SS</u>	<u>MS</u>	<u>F</u>
Stimulus	4	1560.05	390.01	152.98*
Error	5320	13562.85	2.55	
Total	5324	15122.90		

* $\alpha < .01$

Table C-4
Means and Standard Deviations for Stimulus Displays

<u>Stimulus</u>	<u>Stimulus Type</u>	<u>X</u>	<u>SD</u>
e	Photograph	4.72	1.50
a	Photograph	4.39	1.49
c	Line Drawing	4.12	1.65
d	Text	3.53	1.70
b	Text	3.25	1.62

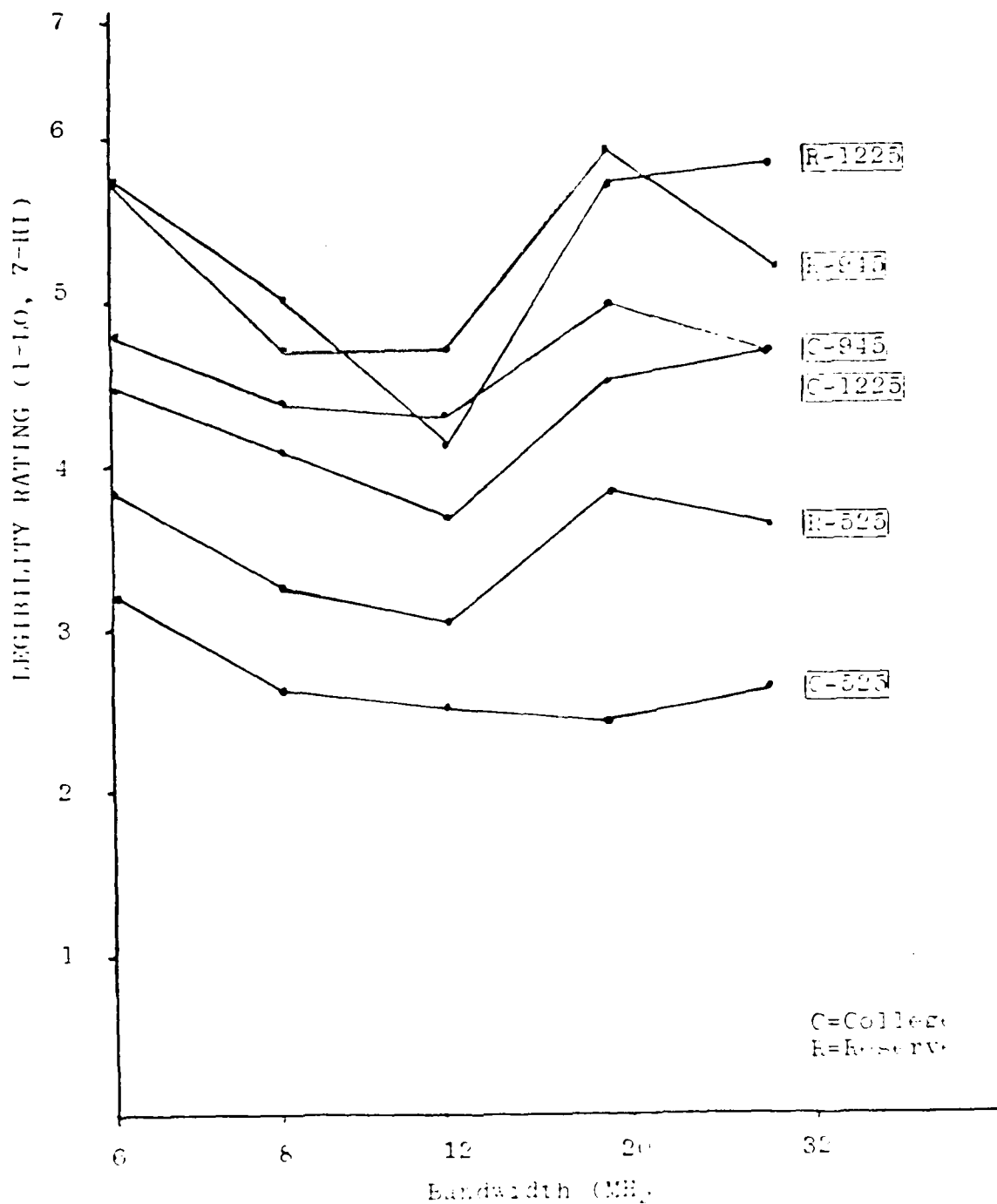


Figure C-1
Bandwidth x Line Rate x Group Means of Image Legibility

The 20 and 32 MHz bandwidths were preferred across all stimuli and the summed scale. The conclusion arising from this study is that a 945 line rate, 20 MHz system is capable of direct photographic page to CRT display conversion for standard page sizes. Shurtleff (1980) also recommends a high resolution (945 lines or higher), high bandwidth, and four to three aspect ratio system for presenting pages of text on electronic displays.

Recent research has been conducted on high definition TV with 1100 - 1500 scan lines using high bandwidth and digital storage and retrieval (Fink, 1980; Fujio, 1980; Sherr, 1979). These technological breakthroughs suggest that the medium and high resolution systems which are rare and costly today will become more plentiful at lower cost in the near future. With high definition TV systems (either digital or analog), photographic conversion is possible for changing of paper-based texts to electronically presented displays.

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APPENDIX D

A COMPARISON OF FOUR TYPES OF USER INPUT FOR ELECTRONIC DELIVERY SYSTEMS

EXPERIMENT V

The component of an electronic delivery system (EDS) which most visibly--perhaps most powerfully--affects the system's speed and accuracy of operation is the instrument of user input. The input medium is the crucial link between the real world and the system. Thus it is crucial to answer the question of which input medium or media available today or in the near future yields the highest accuracy and shortest response time.

METHOD

To answer this question, WICAT tested subjects chosen for their similarity in age and education to actual enlisted men. Four input media which represent the present state of digital input technology were tested: 1) a standard ASCII alphanumeric keyboard, 2) a fifteen key keypad, 3) a simulated touch-sensitive TV screen (hereafter referred to as a touch panel), and 4) a simulated voice input system. In an effort to approximate an actual Army use situation, content typical of that presently used throughout the Army was the stimulus in the experiment. Finally, the experimental procedure was designed to assure accurate measurement of the dependent variables of response time and accuracy rate. In the following paragraphs each of these components will be described further.

Subjects. Two samples of subjects participated in the experiment: a sample of high school students and a sample of Army ROTC students. The demographics of each sample differed, so each will be described separately. Some subjects from each sample participated in each cell of the experiment; this crossing of samples with cells will be reported as well.

The high school sample was obtained by setting up the experiment in the media center of Orem High School (Orem, UT) and recruiting students from an advanced placement biology class. Of the 22 students who participated, 20 (90%) were male and 2 (10%) were female. The average age of the sample was 16.4 years. There was no special remuneration given to the students: they were glad to be released from class to work with an interactive videodisc system.

The ROTC sample was obtained by setting up the experiment in the text issue office of the ROTC building at Brigham Young University (Provo, UT) and recruiting students who responded to in-class announcements, or to an advertising poster in the lobby. Of the 32 persons who participated, 29 (91%) of them were male students, 1 (3%) was a male staff member, and 2 (6%) were female students. The average age of the sample was 23.2 (sd=3.3). The remuneration promised to the ROTC subjects was simply the chance to learn part of the Call for Fire skills they must know to graduate from their officer training, and to learn in a more engaging way than they otherwise might.

The samples were mixed in the following way in the actual experiment: In comparing the keyboard with the keypad, ROTC subjects were used; in comparing the touch panel with the keypad, 4 ROTC subjects and 10 Orem high school subjects were used; in comparing the voice input system with the keypad, 3 ROTC subjects and 12 Orem high school subjects were used. In each comparison, the subjects used one method for each half of their learning time and for each half of their test time.

Apparatus. The apparatus of the experiment was designed to simulate one possible EDS configuration. Thus, the system was a computer-based, interactive videodisc teaching system. The system was not one unit, but rather a prototype union of several devices: 1) a large mini-computer, 2) a telephone modem, 3) a computer/videodisc interface, 4) a videodisc player (and disc), 5) a TV monitor, and 6) a modified keyboard. This system is illustrated in Figure D-1, and will be described in the following paragraphs.

The computer used in the experiment was a DEC Systems VAX 11/780. This room-size computer was chosen to drive the system not because the proposed EIDS would require that much memory, but because the authoring language which WICAT was required to use for the content videodisc (PLANIT) could not be supported on a smaller system.

PLANIT is the computer assisted instruction (CAI) authoring language used to develop the courseware which ran the experimental system. It was developed by System Development Corporation (Santa Monica, CA) under a contract to the National Science Foundation awarded in 1968. The Army Research Institute (ARI) adopted it as the language for its CAI development shortly thereafter.

PLANIT was used for all courseware development associated with another contract which WICAT conducted for ARI. The lesson materials from that project were used for this experiment. Thus WICAT developed a PLANIT front end to process videodisc controller commands. We used this modified language in the Call for Fire instructional

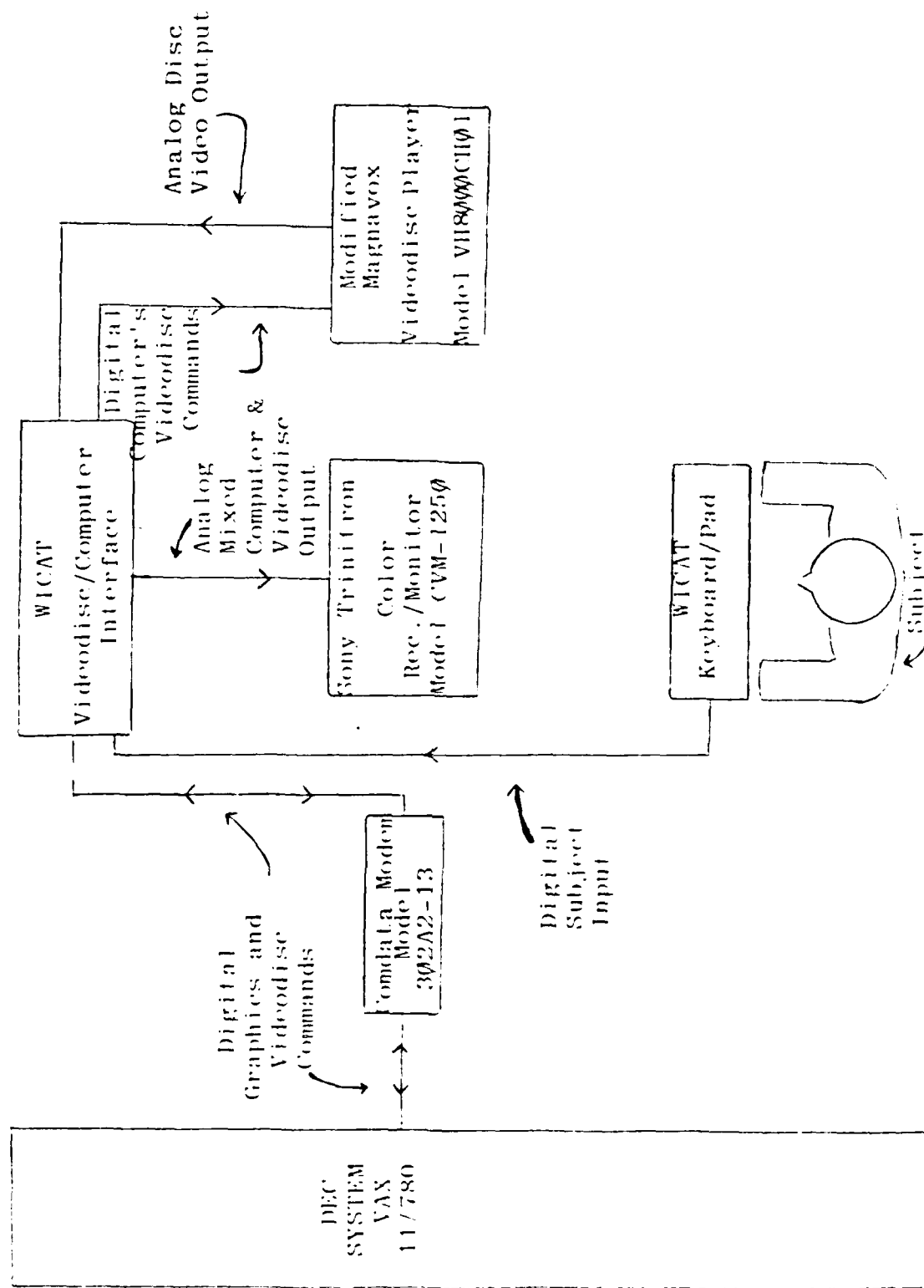


Figure D-1
Block Diagram of Treatment Apparatus

development.

Since the experiment was taken to the subjects instead of bringing the subjects to the experiment, the equipment was, with one exception, portable. That exception was the computer (described above). To allow communication between the computer and the other components, a ComData model 302A2-13 telephone modem was used. It ran at 300 Baud (a slow speed for computer communication).

The modem was connected to the computer/videodisc interface. The computer transmitted digital information over the telephone through the modem to the interface, which then sorted and transmitted the information to either the videodisc player or the monitor screen as appropriate. The interface had the capability of mixing (by use of a Texas Instruments 9918 integrated circuit chip) the analog video output of the videodisc player with the digital video output of the graphics generator in the interface. They could be presented simultaneously on the monitor screen, one superimposed on the other. This resulted in substantial interweaving of the characteristics of normal computer-assisted instruction (CAI), such as answer processing, multiple branching, and guidance feedback, with the television video output and high fidelity stereo output of the videodisc. The player itself was a Magnavox model VH8000CH01 videodisc player which had been modified by WICAT to operate from the interface (as well as from its front control buttons). A videodisc on artillery Call For Fire skills was presented. The disc was produced on one inch videotape at WICAT and mastered and copied by SONY in Japan.

The TV monitor used in the experiment was a Sony Trinitron model CVM- 1250 color receiver/monitor. It was used in the direct video monitor mode. The monitor operated at NTSC standard scan rate, bandwidth, and refresh pattern.

The last component of the system was the keyboard. It was made up of two parts: a standard ASCII keyboard and a modified, 16 key keypad. Thirteen of the keyboard keys were used, each of them interpreted by a symbol table in the PLANIT front end (added by WICAT) to mean some word or phrase corresponding to a required response at some point in the experiment. Each key was labelled with its meaning. Even though the experiment tested four input media, the only real input device was the keyboard; the touch panel and voice input were simulated.

The net result of all these components working together was as follows: the subject was presented with audio-visual instruction, practice, or a test via the monitor. Instruction was punctuated by stops where a response was required. When the subject made a response the presentation continued with the next display dependent on

the content of the subject's response.

PROCEDURE

The experimental design dictated a procedure which consisted of three parts: the assignment of participants to a cell of the treatment, the prefatory explanation and directions given to each subject, and the actual administration of the treatment. The experimental design and each part of the procedure emerging therefrom will be described below.

Experimental Design. To understand how subjects were assigned to cells, the different cells must first be distinguished from one another. The experiment was built hierarchically, the inexpensive input media being compared with each other first, then the "winner of the heat" being compared to each of the more expensive media in order of their price. This was done to give some consideration to the role price will undoubtedly play in the final selection of input medium for the EDS. A hypothesis based on practical considerations is that, of the two inexpensive input media (the keyboard and keypad), the keypad would be both the faster and more accurate medium. Thus, comparing the two simulated input media to the keyboard would be of little value. As a result, an experimental design of three cells was used where the keypad was compared to each of the other three media. Table D-2 illustrates the design.

Assignment of Subjects to Cells. Also noted in Table D-1 is the number of subjects per cell per sample. Note that the ROTC sample fills the first cell and the Orem high school sample dominates the second and third cells. This is a result of the method of assigning subjects to cells. Subjects were assigned to cells predominantly on the basis of when they participated in the experiment. Cell 1 (the comparison of keyboard with keypad) was performed before cells 2 and 3. The ROTC staff offered the cooperation of their students before Orem high school did, so ROTC students became the subjects for cell 1. It is for this same reason that Orem High School dominates the latter two cells.

Prefatory Instructions and Directions. Subjects were taken through the experiment one at a time, with a proctor in constant attendance. Subjects were first seated before the monitor. They were told that they would be instructed in a technique for adjusting artillery fire presently used in the Army, and that they would be tested at its end. They were, however, assured that the test results would reflect on the system they were learning from and not on them. They were

	Keypad	
Keyboard	$n_{\text{ROTC}} = 25$ $n_{\text{Orem}} = 0$	n=25
Touch Panel	$n_{\text{ROTC}} = 4$ $n_{\text{Orem}} = 10$	n= 14
Voice Input	$n_{\text{ROTC}} = 3$ $n_{\text{Orem}} = 12$	n=15

Table D-1
Design of Presentation Features
Experiment Five

told, in addition, that since the system was a prototype, its proper functioning was easily disrupted, and that they should be careful to follow explicitly all directions which appeared on the monitor screen. They were then told that they would be using the two input media indicated by the cell to which they were assigned, one for each half of the instruction and one for each half of the test. They were then told which input medium to begin with and asked to start the instruction.

Content. Every subject received the same content and test. The instruction was arranged in a Rule-Example-Practice-Feedback sequence, and there were three rules to be learned: calculation of an Observer-Target (OT) factor, deviation correction, and range correction. For each rule, the importance of knowing how to use the rule was explained; then the rule itself was given visually with some audio reinforcement as well. Next, one or two examples were given, depending on the concept; and finally four or five practice problems with feedback were given, again depending on the concept.

When all three rules had been learned, subjects were given five simulated binocular views, each with a target and exploding artillery round, and asked to correct deviation and range so that the next shot would hit the target; this required use of all three rules. Corrective feedback was provided with all practice problems so that an incorrect answer would elicit yet another example of how to correctly solve the problem. All practice problems were created to reflect the entire domain of range correction problems encountered in the field with the exception of corrections for altitude changes of a target.

After this, subjects were presented with a fourteen item test where all items were identical in format and skills level to the five comprehensive practice items immediately preceeding them. There was, however, no feedback of any type given for the test items. As an added precaution against untimed study of any items a title header which completely covered the screen was inserted between each problem and held on the screen for approximately five seconds. Also, the monitor screen was blanked between the seventh and eighth items to prohibit casual study of item eight while changing input medium.

Administration of Treatments. The order in which input media were used during the experiment was balanced in the following manner. The choice of which medium to have each subject begin with was first made by the flip of a coin; after that it was alternated for each subject. Half way through the experiment each subject was asked to change input media. At the beginning of the test every other

subject was asked to change back to the first medium, the choice for the first subject again being made by the flip of a coin; the remaining subjects continued with the medium they were currently using. All subjects changed input medium again half way through the test.

The methods of simulating the touch-sensitive TV screen and voice input system were as follows. For the touch panel, a strip of acetate with letters representing appropriate word or phrase responses printed on it was fixed vertically to the left edge of the screen; across the bottom of the screen was placed a similar strip printed with the numerals 0 through 9. When a response was indicated, subjects would touch the letters and numbers on the screen which represented their answer, and as they touched the screen the proctor would type the same answer on the keyboard.

For the voice input system, subjects simply spoke their responses and the proctor typed them. The simulation was further enhanced by requiring subjects to use only the words and phrases designated in the lesson, and to signal a carriage return by some word of their choice used consistently throughout the lesson. It should be noted that the proctor was sufficiently adept at typing to keep up with most student responses, so that his typing was rarely a factor in lengthening the response time.

The dependent variables of response time and error rate were measured with a quartz chronograph stopwatch, but measurements were taken only during the test; it was felt that the instruction and practice should provide time for subjects to become accustomed to using the system, particularly the input media. For each test item the proctor measured the time from initial presentation of the problem to final entry of the subject's answer. All screen erasures, and pauses for thought were included in the response time measurements; this was not thought to be a problem since all input media were used on all problems, and the more difficult items which required more rumination were responded to via every medium, thus distributing their effect evenly over all measurements. An error was defined to be an incorrect answer entered by a subject. Screen erasures were not counted as errors since they were not entered.

After they completed the test, subjects were asked which of the two input media they preferred. They were then encouraged to explain their choice. This information was recorded by the proctor.

Results

Homogeneity of Subjects Within Cells. A comparison of keypad response times and accuracy rates among cells served as a check on the overall homogeneity of the subjects who had been assigned to the different cells. Significant difference between cells in keypad performance (the input medium common to all cells) would indicate a cell-by-medium interaction. Thus, analysis of variance was performed on the mean keypad response from each of the three cells. As is illustrated in Table D-2 below, the F (df=1,53) value of the response time means was 0.34 and that of the accuracy rate means was 0.49; this means there were no significant differences between cells for either response times or accuracy rate. These results were taken as evidence that there was nothing about the cells which constituted a confounded variable in the analysis. Specifically, there was no evidence from this data that the assignment of ROTC students to cell 1 and Orem High School students predominantly to cell 2 confounded the results in this analysis.

Response Times. Analysis of variance was performed on the mean response times for the input media, and the results were as follows: An F (df=3,50) statistic of 25.46 indicated significant differences among the means, and a Newman-Kuels multiple comparisons test showed that 1) the keyboard response time mean was significantly longer than all the others, and 2) the voice input system mean was significantly shorter than all the others. The keypad and touch panel showed no significant difference. These results are summarized in Table D-3.

Accuracy Rates. Analysis of variance yielded an F (df=3,50) value of 1.18, indicating non-significant differences in this set of data. Voice input produced the most errors, even when filtered through a human listener who could ignore noise and interpret different accents and inflections. This difference was not significant in the experiment, but it should be noted that with a mechanical voice input system, the error rate could easily be much higher. Thus these data should not be taken to mean that any voice input system would produce as few response errors as a keypad when used with an interactive, job training videodisc. See table D-4 for a summary of this data.

Preference. Preferences were determined in this study by asking each subject which of the pair of input media used was preferred. Thus all preferences were determined by comparing the keyboard, touch panel, or voice input system with the keypad. However, preferences were approximately equal for all media except the keyboard, which was preferred by only two people out of twenty-five in that cell. Since the binary distributions formed by these ratings were

Table D-2
RESPONSE TIMES AND CORRECT RESPONSE RATES
FOR KEYPAD USE BY CELL

MEASUREMENT	KEYBOARD vs KEYPAD		TOUCH PANEL vs KEYPAD		VOICE vs KEYPAD		F-TEST		
	\bar{X}	SD	\bar{X}	SD	\bar{X}	SD	MS	F	
Response Time	10.26	6.44	10.42	6.72	9.72	6.01	MST	14.1	0.34
							MSE	40.9	
Correct Response	0.903	0.297	0.892	0.304	0.933	0.251	MST	0.0402	0.49
							MSE	0.0823	

Table D-3
MEAN RESPONSE TIMES FOR EACH INPUT MEDIUM

INPUT MEDIUM	RESPONSE TIME	STANDARD DEVIATION		F-TEST	
				MS	F
Keyboard	14.12	8.56	MST	1263.3	25.46
Keypad	10.15	6.39	MSE	49.6	
Touchpanel	10.09	7.62			
Voice Input	6.79	5.24			
Newman-Kuels KB KP TP VI					

Table D-4

MEAN ACCURACY RATE FOR EACH INPUT MEDIUM

INPUT MEDIUM	CORRECT RESP. RATE	STANDARD DEVIATION	F-TEST		
				MS	F
Keyboard	0.886	0.319	MST	0.1127	1.18
Keypad	0.910	0.286	MSE	0.0957	
Touch Panel	0.888	0.317			
Voice Input	0.848	0.361			

Table D- 5

COMPARATIVE PREFERENCE OF KEYPAD TO EACH OTHER
INPUT MEDIUM

MEDIUM COMPARED TO KEYPAD	% WHO PREFERRED KEYPAD	% WHO PREFERRED OTHER MEDIUM	Z-TEST OF HYPOTHESIS THAT PREFERENCES ARE EQUAL
Keyboard	80.0	20.0	4.200*
Touch Panel	50.0	50.0	0.000
Voice Input	46.7	53.3	0.258

approximately normal, a z-test was performed to test these differences in preference in each cell. The great disparity between keyboard and keypad preferences (cell 1) was significant, with a z value of 4.20; preferences in cells 2 and 3 showed no significant differences. These findings are summarized in Table D-5.

In summary then, the simulated voice input system yielded the shortest response times, followed by the keypad and touch panel, with the keyboard yielding the longest response times. There was no difference between the four media in accuracy rate, but this finding is not applicable to voice input with mechanical systems in general. Each system has its own inherent error rate due to factors not a part of this experiment. The only significant difference of preference between media was the low ratings returned on the keyboard.

DISCUSSION

One element of the experiment which affected the results to an unknown degree is the fact that two of the input media were simulated. For instance, subjects occasionally made comments like this: "I'd have liked the touch panel more if it were real." Thus, it is unwarranted to assume that the simulations were totally effective; there was an artificial atmosphere about the touch panel and voice input.

As an adjunct to this study, the project team investigated a number of voice input systems, including the Heuristics, Interstate, and Threshold systems. Prices were obtained for the cost model. The error rates on all system but the expensive Threshold system appeared to be much higher than the 15% observed in this simulation.

An aspect of the experiment closely related to that above is the artificial ease with which the voice input system operated. Actual voice input systems usually require training, both of the user and the system, where the interactions of voice and word idiosyncrasies for each individual user are determined and stored in the system's memory. Even after this extensive training the "hit rate," or percentage of user input words which are correctly interpreted by the system, is not perfect. Added to this inaccuracy is the complication that a voice input system seeks to interpret everything it receives as a word in its limited vocabulary; this means that a person thinking out loud to himself must either turn off the microphone of the voice input system or risk having some murmurings accepted as input if they are close to a stored utterance.

None of these weaknesses of a voice input system were simulated in the experiment: The keyboard operator never entered murmurings as a bona fide response; there was no training other than simply telling subjects to mark the end of every response with the same word, and the hit rate on the simulated system was much more nearly perfect than that which a real system could have generated. Because of this artificially efficient input system, it is reasonable to believe the response times it yielded are artificially small.

It should be noted, however, that the keyboard and keypad media were not simulations. Also, the characteristics of the simulated touch panel, while minimizing the otherwise real danger of errors due to parallax (and generating some embarrassment in subjects who used it), nevertheless was a relatively accurate reproduction of an actual instrument. And lastly, the voice input simulation, for all its shortcomings, still reproduced the grosser characteristics of a real system fairly well. For these reasons the results of this experiment can be applied to some degree to input media in the real world. It can, for instance, be safely concluded that, with high quality equipment and proper training, users of voice input systems can approach the speed of response exhibited in the experiment; it can also be concluded that the conventional keyboard input medium is, for most people, both sufficiently difficult and irritating to suggest the use of a different input medium when circumstances permit.

However, again practical considerations should not be excluded. There is the matter of expense. Keypads are by far the least expensive of the input media tested, available in large quantities for less than \$10 per unit. Next in price are keyboards, currently selling for \$50 to \$150 per unit for large orders. Touch panels are higher still in price, starting at \$500 and quickly escalating from there, and most expensive of all are voice input systems, priced from \$3000 to \$18,000. With these ballpark figures in mind it should be apparent that the quicker response times of voice input systems are dearly bought and that the 3 to 7 seconds and the freeing of the user's hands for other tasks gained by their use must be fairly important to justify the expense. On the other hand, though, these figures serve to reinforce the commonly observed negative response to conventional keyboards for training purposes, since the less expensive keypad can often suffice.

Finally, the purpose of a system should have a substantial effect on the choice of input media attached to it. For instance, despite the long response times and low preference ratings associated with the keyboard, it is the only input medium of the four tested which would adequately serve purposes requiring input of free text. In another situation--one requiring a relatively limited number of

responses and undivided attention to a photoelectronic display--a touch panel would serve best, since users could respond without diverting attention to extraneous devices. Touch panels might also be useful for applications where compactness and portability are critical, since they are not physically separate from the display. A voice input system could prove cost effective in situations where quick response times are important or where the user's hands are occupied with different duties. The keypad could be considered the workhorse input system, being suited for general purpose, limited response applications.

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